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ABSTRACT

For the past two decades, increasing numbers of scientists have been optimistic about finding other intelligent life forms in our galaxy. On the other hand, as knowledge has grown regarding how life developed on earth, a scientific counterrevolution has evolved. Simply stated, it questions the inevitability of widespread life within our galaxy, let alone elsewhere in the vast universe. These scientists believe that the first extraterrestrials we shall meet will be our own grandchildren, and not some alien intelligent beings. Various speculations and probabilities concerning the existence of extraterrestrial life are explored including where intelligent life may exist, characteristics of such life, methods of contact, and evidence indicating the existence of intelligent, extraterrestrial life. Additional topics discussed include planetary atmospheres, stars, evolution of life, natural selection, and implications of these topics for intelligent, extraterrestrial life. United States and Soviet space programs, space colonization, and interstellar travel are also discussed. (Author/JN)

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INTELLIGENT LIFE OUT THERE: ARE WE ALONE?

by

Boris Blai, Jr., Ed. D.
Psychologist in retirement

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Dedicated to:

Adam, Amber, Brandi,

Carolyn, Pamela & Spring:

our grandchildren.

And Liz, my wife.

With love.

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INTELLIGENT LIFE OUT THERE:
ARE WE ALONE?

PREFACE

Speculation: - humans are not the only intelligent life form in the universe. The existence of such life beyond Earth, apart from being a prerequisite for the existence of intelligent life, has been the subject of speculative thinking for as long as mankind has existed.

"An important theme in Western religion has been the special relation of the human race to the Deity who, according to religious tradition, created it. In ancient and medieval times the unique relation of man to God was emphasized by astronomical schemes that placed the Earth at the center of the Universe, with the various celestial bodies revolving about it. This support to our vanity was removed by the findings of modern astronomy. The Earth was relegated to the position of a minor planet circling an undistinguished star which itself is far from the center of its galaxy. The galaxy is also just one of a large number of similar bodies which dot the universe." (Feinberg and Shapiro, 1980: p. 21).

Today, a new dimension exists in such speculation about the existence of extraterrestrial intelligence (ETI). No other generation has had the opportunity and technology to reach beyond our own planet. However, we are now able to see, to touch, and to hear the forces that we believe shape our universe. In just over two decades, mankind has ingeniously explored five distant planets--and additionally, two dozen moons. We have probed their weather and topical surfaces. We have landed on some, examined the atmospheres of others, and monitored their radio noises.

What can be deduced theoretically from the known laws of science regarding the probability that extraterrestrial, intelligent life exists? Are there many other planets which, like Earth, are abundant with life forms, or

is Earth..."a unique oasis in a vast, utterly barren cosmos?" (Feinberg & Shapiro, 1980: p. 19).

For the past two decades, increasing numbers of scientists have been very optimistic about the liklihood of finding other intelligent forms of life in our own galaxy. On the other hand, as our knowledge has grown regarding how life developed on Earth, a scientific counterrevolution has evolved. Simply stated, it questions the inevitability of widespread life within our galaxy, let alone elsewhere in the vast universe. These scientists believe that the first extraterrestrials we shall meet will be our own grandchildren, and not some alien intelligent beings.

Quite understandably, when we turn from the realm of hard facts to speculative thinking, disagreements often arise as to what is reasonable conjecture and what is not. This monograph examines the school of thought which evolved subsequent to a conference at the National Radio Astronomy Observatory in Green Bank, West Virginia, in 1959. It is for you, the reader, to conclude whether or not the speculations and probabilities discussed are reasonable ones. You must decide if they may be accepted tentatively pending future disclosure of hard-fact evidences for the existence of extraterrestrial, intelligent life forms.

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1982

INTRODUCTION

> If ever we get a message from intelligent life outside our planet, that will be the most exciting event in all of history.
>
> C. P. Snow

The idea that humans are not the only intelligent beings in the universe is an old one, and the phenomenal success of Star Wars strongly suggests that this idea has lost little of its appeal to modern man. Beginning with a conference at the National Radio Astronomy Observatory in Green Bank, West Virginia, in 1959, a school of thought has evolved among scientists that has added weight to the sense that we, Earth's human population, are not alone.

However, as our knowledge has grown of how life developed on Earth, scientific controversy has arisen regarding the inevitability of widespread life in our galaxy, let alone other galaxys throughout the utterly vast cosmos. In this document, we examine the knowledge, both pro and con, for the existence of intelligent, extraterrestrial life. Yes, there are responsible, scholarly scientists who firmly believe that the first extraterrestrials we will meet will be our own grandchildren returning from space voyages.

Assuming that the rest of the universe is pretty much like our solar system, one can offer optimistic, pessimistic, and conservative answers to such fascinating questions as:

1. What is the rate at which stars like our sun are formed?
2. What is the probability that these stars will have planets?
3. How many planets are capable of supporting life?
4. What is the probability that life will develop on these planets?
5. What is the probability that life will be intelligent and capable of interstellar communications?
6. What will be communicated?
7. What will be the duration of such attempts at communication?
8. What if extraterrestrials decide to colonize other systems rather than simply communicate with them?

For sheer convenience, throughout this document the standard abbreviation, ETI, will be used rather than writing the words "extra-terrestrail intelligence." Similarly, SETI will denote the "search for ETI."

To facilitate the writing of very large and very small numbers, the powers-of-10 notation will be used. Briefly, in this notation system, a small number like .0003 is written 3×10^{-4} and very large numbers like 5,000,000 are written 5×10^{6}. This "shorthand" notations system will avoid cluttering up these pages with an excess of zeros!

The rules for arithmetic in this powers-of-10 notation system are:

1. To multiply two numbers, multiply the two terms in front of the power-of-10, and then add the exponents of the 10s. For example: $(2 \times 10^{5}) \times 4 \times 10^{4}) = 8 \times 10^{9}$, or 8,000,000,000.
2. To divide two numbers, divide the numbers in front of the powers-of-10, and then subtract the power of the denominator from the power of the numerator. For example: $(4 \times 10^{5}) - (2 \times 10^{4}) = 2 \times 10^{1}$, or 20.

WE ARE PROBABLY NOT ALONE

(Note: This section is a synthesis of a report prepared by Marcia S. Smith. Please see "References" at the end of this document.)

> As we learn more about mankind and the universe we live in, the more likely it appears that what we call intelligence may exist beyond the bounds of our planet. In order to respond, rationally, to this possibility, we must carefully study and understand the knowledge that already exists in this field. This article is one such attempt to achieve such understanding. (Smith, 1977: p. 3)

Today, prominent scientists are openly and seriously studying methods designed to determine if there are other civilizations, and if so, how to make contact with them. However, this line of inquiry is quite different from the study of unidentified flying objects (UFOs). Many who support the thesis that there are other intelligent civilizations, do not support the claim that they have visited the Earth. The remainder of this section examines past and current thought on the possibility that there is intelligent life elsewhere in the universe, and also discusses the possible impact of making contact with it.

Extraterrestrial Life Elsewhere?

The long-standing belief that the only intelligent life in the universe exists on our planet, Earth, is gradually disappearing. As far back as the 13th century, philosophers were vigorously speculating on the possibility of other planets in the universe supporting intelligent life, and prior to this time such speculations were evidenced in mankind's on-going curiosity about the world and the universe. Once it was discovered (and accepted) that Earth was not the center of our solar system, let alone the entire universe, speculation on the possibility of extraterrestrial life-forms with intelligence was intensified. At first, these ruminations focused on the planets of our own solar system.

Today, however, scientific thought maintains that if any life other than our own does exist in our small corner of the universe, it is of a simple biological form only, not what we would term intelligent life. On the other hand, recent estimates of these same scientists suggest a probability of as many as one million advanced civilizations existing in the Milky Way galaxy alone. This particular galaxy is the one which contains our Sun and its solar system.

To try to grasp the immensity of space and numbers of stars involved, astronomers calculate that there are approximately 100 billion stars (other than our sun) just in the Milky Way galaxy alone! In addition, there are some 10^{22} (that's 10,000,000,000,000,000,000,000) stars in the known universe! Any of these could conceivably have planets orbiting them (just as Earth does the Sun), and any of these planets might possibly support some type of life.

In their SETI, scientists have begun to identify methods for contacting other civilizations that might exist in the universe. The categories of possible search methods are: (1) electromagnetic waves, and (2) spaceships--manned or unmanned. As might be anticipated, there are advantages and disadvantages to both.

Electromagnetic signals--either radio or light waves, can travel at the speed of light (186,000 miles per second.) However, they convey only small amounts of information at a time. Consequently, they require very long periods of time for two-way communication.

Ships can carry artifacts or passengers to communicate a more complete picture of our Earth, its people and cultures. However, according to currently accepted laws of physics, they cannot travel at the speed of light. Although the technology is now available for sending or receiving electromagnetic signals, spaceships travel at a mere fraction of the speed of light and we do not presently know how to alter the human life-cycle so that manned ships could travel through space without regard to the short life-span of humans.

Unmanned space probes already have been launched (Pioneer 10 and 11, and Voyager 1 and 2). These carry greetings from the planet Earth. However, it seems to be more likely that our technology will develop to the point where future spaceships will literally pass these products of our present-day technology on their way through interstellar space, much as jets pass propeller airplanes.

There is no question that certain risks are involved in coming in contact with an alien, possibly superior intelligence. The consequences would undoubtedly depend in part upon (1) whether the contact is a face-to-face encounter--one in which "they" arrive at our doorstep, or (2) whether we have intercepted a radio signal from "them." Obviously we would have no control over the above number (1) situation, but in the case of number (2), we would presumably be relatively "safe" since there is no requirement for us to respond.

Although we on Earth have been transmitting radio signals for about fifty years, only extremely sensitive receivers could detect them, so our existence may well be unknown to any extraterrestrial intelligence which may exist. In addition, if we on Earth intercept an extraterrestrial signal, we have the option to respond or not respond. By listening to their transmission, we could, perhaps, assess their nature and their intentions towards other species. Obviously though, we could be wrong in our assessment if "they" wanted to deceive us by transmitting messages that appear beneficient, while in reality their intentions are malevolent.

Some possible benefits that might accrue from establishing communications include such areas as: language, culture, basic science, and species survival itself. Caution, however, would be dictated in accepting any advice initially. A 1971 report (Project Cyclops: A Design Study of a System for Detecting Extraterrestrial Intelligence: Moffett Field, California, NASA, 1973) on a system to detect interstellar signals, by Stanford University and the

National Aeronautics and Space Administration (NASA), offered the following observations:

> We cannot assert that interstellar contact is totally devoid of risk. We can only offer the opinion that, in all probability, the benefits greatly outweigh the risks. We cannot see that our security is in any way jeopardized by the detection of signals radiated by other life. It is when we respond to such signals that we assume any risks that may exist.

Before a major search program can be initiated, however, target planets having a strong probability of supporting intelligent life must be identified. The first step in this process, selecting those stars which have planetary companions, is the work of astronomers. There have, in fact, been several which astronomers have claimed do evidence planet companions--but all of these have since been questioned by other scientists (astronomers) who claimed that the data collection techniques were faulty.

Currently, scientists can search for signals from other civilizations with radio telescopes. However, they are limited not only by the technology of the receivers, but also by interference from radio waves emanating from devices such as satellites, commercial radio and television. The frequency band which many scientists conclude is the most likely to carry messages from other intelligence, 1420-1700 megahertz, is becoming increasingly crowded with other services. If the present pace continues, receivers may not be able to distinguish between man-made interference and a signal arriving from space, regardless of how advanced radio telescope technology becomes. If a search is to be conducted, either the 1420-1700 band will have to be reserved exclusively for such sctivities, or the receiving antennas located outside the zone of interference from Earth-related systems; perhaps on the far side of the Moon.

For decades man's imagination has been filled with stories of life on other planets within our solar system; Mars being a frequent selection. There are few, if any, scientists now believing that intelligent life exists

on Mars (or any planet in the solar system other than Earth). However, many hope that basic life forms may, such as simple replicating chemicals or bacteria. The search for such simple life is an on-going project. Mars has been an especially tempting target, and the first planetary biological probes, Viking 1 and 2, were sent to Mars in 1975. No conclusive, ambiguous evidence was found for the existence of life. It will be left to future Martian probes to make further experiments in order to determine whether there is life on Mars.

Neither the Earth's moon nor the two moons of Mars have atmospheres, so life probably would not develop there. The planet Mercury has an atmosphere less than .1% as dense as Earth. Surface conditions on Mercury have been described as the harshest of any planet in the solar system. The temperature extremes of 350 degrees day and minus 170 degrees night, coupled with the large amount of solar radiation received due to its proximity to the Sun, makes the possibility of life virtually negligible.

Venus, often described as the Earth's sister planet, has about the same size, density, and mass as Earth. But the similarity certainly ends there. Venus is enshrouded by a ubiquitous cloud which creates a "greenhouse" effect, where energy arriving from the Sun cannot be radiated back into space. This creates very high surface temperatures (up to 500°C) and pressures (over ninety times that of Earth).

The Venusian atmosphere consists primarily of carbon dioxide, and its clouds are thought to be composed of such corrosive compounds as sulfuric acid. These conditions, together with the high pressure and temperature of the surface, make the development of life on Venus unlikely, at least in this stage of its evolution.

Asteriods, ranging in size from hundreds of kilometers in diameter to a particle of sand, lie in a belt between the orbits of Mars and Jupiter. The largest asteroid, Ceres, is 955 kilometers in diameter, more than twice the size

of the next largest, Pallas. Atmospheres have not been detected on any of the asteroids; they are unlikely candidates for life evolution.

Jupiter is the largest planet in our solar system. Since we cannot see through Jupiter's cloud layer, our postulates about the planet depend largely upon visits of planetary probes Pioneer 10 and 11. Current thinking envisages a planet with a small rocky core, surrounded by two layers of liquid hydrogen and an atmosphere. The atmosphere has been shown spectroscopically to consist of hydrogen, helium, ammonia, methane, and water. Jupiter is hot--very hot! The core is speculated to have temperatures about 30,000°K, (K = degrees Kelvin. 0° Kelvin = absolute zero, or -273°C), and the inner layer of hydrogen temperatures are around 12,000°K).

Although these conditions would seem inhospitable to life, some scientists are optimistic that organisms might evolve in the more temperate regions of the atmosphere. The four elements which, together with abundant energy, are thought necessary for formation of basic building blocks of life (such as amino acids) have been observed in the Jovian atmosphere: these are ammonia, hydrogen, methane and water. Particles, both liquid and solid, are also present and could provide protected areas for the development of organic life.

Jupiter has thirteen known moons, only one of which is known to have an atmosphere, Io. Surface pressure on Io is estimated at only one billionth that of Earth; conditions are not thought promising for the development of life on this satellite.

Saturn, the second largest planet in our solar system is thought to resemble Jupiter. However, it is colder since it is much further from the Sun. The atmosphere which surrounds Saturn has been spectroscopically observed to contain methane and hydrogen. Scientists also suspect that ammonia is present on Saturn, as it is on Jupiter, but that the lower temperature cause it to exist in a solid layer so far down in the clouds that it cannot be detected from

Earth. Like Jupiter, Saturn radiates more heat than it receives from the Sun. With its very cold temperatures, the possibility of life seems bleak.

Saturn has ten known moons, one of which, Titan, has a dense atmosphere; its main constituents appear to be methane and hydrogen. Scientists think that if there is any thermal or volcanic activity on Titan, temporary pools of warm water might exist which could provide the medium for development of life.

The seventh and eighth planets in our solar system, Uranus and Neptune, remain mysterious, since their distance from the Sun makes them even more difficult to observe than the planets discussed above. Both are thought to have rocky cores common to other planets. Surrounding these cores is an 8,000 kilometer layer of water and methane, and a deep atmosphere. Spectroscopically, these atmospheres evidence the presence of methane, hydrogen, and helium.

The extremely cold temperatures on Uranus and Neptune would seem to make the possibility of life development very small. The five moons of Uranus and the two moons which orbit Neptune have not been observed to have atmospheres, so are not good candidates for life either.

It is therefore concluded that the best chance for life, other than on Earth, is on Mars, Jupiter and Titan. However, it cannot be ruled out on any of the bodies in our solar system, especially those with atmospheres. It is to be noted further that the term life refers solely to simple organic life, such as amino acids, not intelligent life forms capable of building cities or spaceships. Any search for the latter type of life would have to be expanded to other parts of our Milky Way galaxy.

Intelligent Life Elsewhere?

What are the possibilities of other intelligent life in the universe? The first meeting in modern times to discuss the possibility of extraterrestrial intelligence was held by the National Academy of Sciences in 1961 at Green Bank, West Virginia. Five years after this meeting, Dr. Carl Sagan, Biologist and

Astronomer, Cornell University, came to a different conclusion than did the Green Bank group. The conclusion from the group's deliberations was that there are between 40,000,000 to 50,000,000 extant civilizations capable of communicating with us. Dr. Sagan's calculations yielded a spread of 10 to 1,000,000. It is quite evident from these differing calculations that determining the number of neighbors we have is a highly speculative and subjective process.

In 1972, a group of fifty-four scientists from the United States, United Kingdom, Soviet Union, Hungary and Czechoslovakia met to discuss means of finding other intelligent civilizations. In their conclusions, the group recommended the following research directions:

1. A search for signals and for evidence of astro-engineering activities in the radiation of a few hundred chosen nearby stars and of a limited number of other selected objects, covering the wave length range from visible to decimeter waves, using the largest existing astronomical instruments.

2. A search for signals from powerful sources within galaxies of the local group including searches for strong impulsive signals.

3. Exploration of the region of minimum noise in the submillimeter band, in order to determine its suitability for observing extra-terrestrial civilizations.

4. The definition of a system for keeping the entire sky under constant surveillance, which could lead to a search of wider scope than those listed under 1 and 2. (Sagan, 1973, p. 182).

In 1974 the National Aeronautics and Space Administration established an Interstellar Communications Study Group at Ames Research Center, Moffett Field, California. The four principal conclusions reached by the Science Workshop Group were:

1. It is timely and feasible to begin a serious search for extra-terrestrial intelligence;

2. A significant SETI program with substantial potential secondary benefits can be undertaken with only modest resources;

3. Large systems of great capability can be built if needed; and

4. SETI is intrinsically an international endeavor in which the United States can take a lead.

(Smith, 1977, p. 48)

The Soviet Union has had a long-standing interest in finding other intelligent life in the universe, and has performed searches with radio telescopes. In March 1974, the Board of the Science Council of the Radio Astronomy Problem Area of the USSR Academy of Sciences approved a research program for communication with extraterrestrial intelligence, designated as CETI (Communication with Extraterrestrial Intelligence). The basic principles of this program are:

1. Efforts to detect extraterrestrial civilization should proceed smoothly and systematically, and should extend over a prolonged period of time. The program is oriented in this direction from the very outset. It would be a great mistake to build a program in contemplation of rapid and easy success.

2. Investigations should be based on a specifically devised program (or group of programs) which would be revised and perfected as time passes. The program should provide easy opportunity to take advantage of existing technology (radio telescopes, antenna systems and associated instrumentation), and should also envision the development of specialized techniques and equipment for coping with the CETI problems.

3. The program will recognize that astrophysical information will be acquired as a byproduct of the search for signals from extraterrestrial civilizations. When actual investigations are undertaken it will be necessary to analyze carefully the question of what astrophysical applications can be pursued during the search activities.

4. In view of the uncertainty in our prior knowledge as to the character of signals from extraterrestrial civilizations, the program should entail parallel studies in several directions. (Smith, 1977, p. 51)

Professor Iosif Shklovski, best known in the West as co-author in 1966 of Intelligent Life in the Universe, with Professor Carl Sagan (Cornell University, authored an article in which he concludes:

> ...even from the now widespread optimistic idea that the closest extraterrestrial civilizations are 200-300 parsecs from us, (A parsec = 3.26 light years and a light year = 5.8×10^{12} miles: that's a minimum distance of 3,781,600,000,000,000 miles--or--3 quadrillion, 781 trillion, and 600 billion miles), we must view ourselves as being virtually

> alone. For in the region of our Galaxy with a 300 parsec radius there are about 10 million stars, graphically demonstrating the rarity of the phenomenon of rational life in the universe. (Shklovski, 1977, p. 37)

Intelligent Civilizations: Where?

Among some 100 billion stars in the galaxy and 10^{22} in the known universe, (that last number is 10 sextillion, or 10,000,000,000,000,000,000,000), where should the search for other intelligent civilizations begin? Walter Sullivan lists three requirements for life: "Star size--a sun of proper warmth and longevity; Planet size--A planet massive enough to retain an oxygen atmosphere and small enough to allow its hydrogen to escape; Temperature--A temperature at which water is liquid." (Sullivan, 1966, p. 39)

Assuming planets do exist around distant stars, how could they be detected from Earth? At the vast distances involved, "seeing" a planet is extremely difficult. The method currently in use involves the study of perturbations in the orbit of a star, and it is called Astrometry. Dr. George Gatewood, Director of the Allegheny Observatory derived a "planetary detection index" to calculate how massive a planet would have to be in order to be detected around certain stars. Using this formula he calculated the index for thirty-six stars within sixteen light-years of our Sun. In addition, Dr. Gatewood chose thirty-three other stars which he proposed be surveyed for the perturbative extrasolar planetary systems.

What Method of Contact?

Having identified a few places to look for intelligent extraterrestrial life, what methods of contact are available? There are three: (1) electromagnetic signals; (2) unmanned probes; and (3) manned ships. For all three, communications can be initiated from either civilization. It is of interest to note:

> That the NASA Interstellar Communications Study Group chose to change the acronym CETI, for Communications with Extraterrestrial Intelligence, to SETI, for Search for Extraterrestrial Intelligence. The change was made to emphasize that at

> this point in time, at least, their concern is with finding a signal, not responding to it. A decision on whether or not to respond would have to be made after analysis of the message's content, which could take decades. The Soviet Union still uses the CETI acronym, however, which probably is not indicative of a stronger desire to respond to any received message, but simply a difference in perception of the need to specify which approach they intend to take.
>
> (Smith, 1977, p.54)

In receiving electromagnetic signals, there are two requirements: it must be distinguishable from the background noise of space (for all matter in the universe emits radio waves encompassing all frequencies, and stars radiate a great deal of light); and must be modulated or differentiated so there is no doubt as to its intelligent origin." (Foster, 1972, p. 27)

In searching for signals from other worlds, there are two problems encountered. The first one, where to look, has been briefly discussed above in the section headed--"Intelligent Civilizations: Where?" Between 1960 and 1975, nine investigators searched different targets which covered....."less than 0.1 percent of the number that would have to be investigated if there were to be a reasonable statistical chance of discovering one extraterrestrial civilization". (Sagan & Drake, 1975, p. 28)

The second problem in the search is knowing the frequency they would use in their transmission. Project Ozma was the first search for signals from other worlds in 1960. It was directed by Dr. Frank Drake at the National Radio Astronomy Observatory in Green Bank, West Virginia. It studied the stars, Tau Ceti and Epsilon Eridoni. Project Ozma did not detect any signal from another civilization. A follow-up, Ozma II in 1972, was also unsuccessful in locating signals from another civilization. The seven other searches attempted during the 1960-1975 years were all singularly lacking in success.

Should a signal ever be received, a problem of great import is how to decode it. Without a common language, how could the two civilizations communicate? In order to transmit specific information, Hans Freudenthal in Holland developed

an appropriate language, Lingua Cosmica or LINCOS, free from grammatical inconsistencies and based entirely in the form of semantics. It is a coded system of units, therefore cannot be spoken. The view has been expressed that....."a linguistic system based upon these fundamentals would be far easier to decipher than many of the written languages of ancient civilizations which have been deciphered by archaeologists. (Shkloski and Sagan, 1966, p. 78)

A matter of grave concern to those scientists interested in conducting SETI searches is that if action is not taken, the radio spectrum will become crowded to the extent that a message arriving from another civilization could not be detected. Two radio signals of the same frequency cannot occupy the same space at the same time. If they try, they interfere with each other (called radio frequency interference--RFI).

In an effort to alleviate this problem, the United States submitted a question to the International Radio Consultative Committee. By November 1976, the necessary twenty signatures from other CCIR members had been received, and it therefore became an "official" CCIR question. The text of the question read:

Question 17/2
Radiocommunication Requests for Systems
To Search for Extraterrestrial Life

Considering:

(a) that many scientists believe intelligent life to be common in our galaxy;
(b) that electromagnetic waves are presently the only practical means of detecting the existence of intelligent extraterrestrial life;
(c) that it is believed to be technically possible to receive radio signals from extraterrestrial civilizations;
(d) that although it is not possible to know the characteristics nor to predict the time or duration of these signals in advance, it is reasonable to believe that artificial signals will be recognizable;
(e) that an artificial radio signal of extraterrestrial origin may be transmitted at any frequency, it is technologically impractical to search the entire radio spectrum but the band searched should be

sufficiently wide to make detection of a radio signal reasonably practical;

(f) that technological and natural factors which are dependent on frequency determine our ability to receive weak radio signals;

(g) that while the search for radio signals from extra-terrestrial civilizations has already begun, more sensitive systems will be in use by the 1980s which could receive harmful interference from very weak man-made signals;

(h) that it is necessary to share the bands in which the search is conducted with other services;

(i) that available technology will allow a search for these signals from the earth, from earth orbit, and eventually - from the moon, and to minimize interference, certain locations on earth and in space may be preferred." (Smith, 1977, p. 81)

Attempts to detect signals from other civilizations can provide practical knowledge as to what should be included in any signal we might send into space to announce our existence. These signals could be either in the frequencies used by radio or those by light via lasers.

In a sense, Earth has been 'announcing' its existence for years, since transmissions from commercial radio and television stations are similar to those that would deliberately be sent. Large scale radio communications began about fifty years ago, which means that a wave front of these stations is now about fifty light years distant, available to be detected by other beings. As Carl Sagan soberly observed:

> "There are two general channels which are in heavy commercial use and which are transmitted by the territorial ionosphere...the entire television band and....the high frequency end of the AM broadcast band. ....Thus the characteristic signs of life on Earth which may be detectable over the interstellar distances include the baleful contents of many American television programs and the mindless outpourings of rock-and-roll stations."
>
> (Shklovski & Sagan, 1966, p. 49)

In point of fact, a discussion of the merits and demerits of announcing our existence to the universe is largely academic for it has already been done. (In December 1974 - the 16th to be precise - Frank Drake and Carl Sagan transmitted the first intentional signal from the Arecibo Observatory in Puerto Rico.)

These signals took less than three minutes to transmit. They were aimed at the Great Cluster of Hercules, a group of 300,000 stars called Messier 13. This target was selected because at its distance from Earth (24,000 light years) it has the same angular size as the transmitting beam will have at that distance. Thus - all the stars in the cluster will receive the signal, and Sagan estimated a 50-50 chance of a civilization existing there. With a round trip signal travel time of 48,000 years before a possible comparable message could reach the Earth, the concern for the safety of our planet is not overwhelming.

Laser, (i.e., Light Amplification by Simulated Emission of Radiation), also known as an optical maser, are intense, narrow beams of light, and since they can be transmitted from very narrow apertures, they dissipate less rapidly and can be pulsed at powers up to 50,000,000 watts. By using a filter, a monochromatic (single color) beam is possible. This is advantageous to distinguish laser beams from stellar radiation; i. e., the light emanating from the Sun. In 1974 and 1975, a NASA satellite was used to search for ultra-violet laser beams, but without success.

Although radio and light waves travel at the speed of light, (the fastest method of communication over the vast distances of interstellar space), there are other methods of interstellar communication, such as sending unmanned probes and manned spaceships.

Ronald Bracewell, a radio astronomer at Stanford University, suggested as early as 1960, that radio signals are uneconomical as a way to contact other civilizations. He recommended unmanned automatic probes as an alternative.

Earth has already sent its first interstellar messages by unmanned probes. Pioneer 10, which provided the first good look at Jupiter, and its sister Pioneer 11, now enroute to Saturn, will both eventually leave our solar system. Even though these space probes are the fastest vehicles ever launched, one would not reach the nearest star for 80,000 years. The best chance for one

of the plaques carrying messages to reach another civilization is if that race travels in interstellar space and one of their ships picks it up. As Sagan notes: "Placing a message aboard Pioneer 10 is very much like a shipwrecked sailor casting a bottled message into the ocean - but the ocean of space is much vaster." (Sagan, 1973, p. 64)

In the Fall of 1977, the United States launched two Voyager spacecraft to Jupiter and Saturn. Since these probes will also leave our solar system, a two-hour record has been made onto a copper disc and attached to the side of each spacecraft, together with a needle and instructions how to operate the device. As with the Pioneer spacecraft, the only real chance Voyager has of delivering its message is if another civilization travels in interstellar space and picks it up. Then, of course, the aliens would have to determine how to work the 'record player'.

In 1973, the British Interplanetary Society set up Project Daedalus to study the possibility of sending an unmanned probe to a nearby star using science and technology expected to be available by the year 2000. The simplest mission model was chosen, a one-way decelerated flyby, and Barnard's Star was selected as a target, since it is only six light years distance from Earth. This would permit a travel time of about 40 years, allowing some of those involved with the probe's launch to also be associated with the completion of the mission. The group also decided that an external ignition, a nuclear rocket capable of accomplishing the mission, was the only type of propulsion expected to be available by the end of the century.

The third method of contacting another civilization is manned space ships; a means for possibly achieving actual physical contact. The time involved in radio communication is enormous. For example - it will be 48,000 years before we know if anyone in Messier 13 received the message sent out from Arecibo in 1974. There may be no one left on Earth to receive the message-answer, and all would have been in vain. However, with manned spaceflight, there would at least be the crew members, or their descendents, to carry tales of Earth. Our culture and knowledge could survive.

Unfortunately, the distances involved are the same, and the speed at which we could travel could be slower than electromagnetic signals. Einstein's theory of relativity does not permit objects to travel at or faster than the speed of light. If the necessary propulsion systems were available, the fastest that man could travel would be .99 the speed of light, and the round trip to the nearest star would be eight years. In order to have a reasonable chance of contacting another civilization, plans would have to assume traveling many, many years beyond that. This then raises the question of how to do so within man's short lifespan.

Of the several future propulsion methods receiving consideration by interested scientists, the three most often discussed are: 1) nuclear fusion; 2) an interstellar ramjet using atoms in interstellar space as fuels; and 3) a matter-antimatter reaction. Once the propulsion debate is solved, there still remains the matter of man's short lifespan. Journeys to other worlds could take thousands of years - and presently, homo sapiens' lifespan is about 70 years.

Three methods of dealing with this dilemma have been proposed. Others, however, are conceivable; such as generation spaceships. Of the three methods, the first two are closely related; i. e., 1) hibernation, and 2) suspended animation. These each involve slowing the metabolic rate, with hibernation being a natural process and suspended animation being induced by external means. The third option - relativistic travel - is more related to propulsion systems, since the spaceship's speed must be very close to the speed of light for the physical laws to apply.

If hibernation could be induced in humans, this could solve the human problem of interstellar travel; at least those problems associated with the short lifespan of humans versus the extended periods of time needed to travel to other star systems. One would not have to worry about traveling near the speed of light, for the crew would not age as fast and would have more time to reach their destination.

Based upon the theory of relativity, relativistic travel; i. e., near the speed of light, is accompanied by the phenomenon of a clock on a speeding spaceship running slower than one on a stationary home base. With relativistic travel, man could not only reach, within a human lifetime, the center of our galaxy - which is the most densely populated area - but to other galaxies as well. Such relativistic travel time can be shown as:

$$T = T_o\sqrt{1 - \frac{(v)^2}{(c)}}$$

where T is the time on the spaceship; T_o is the time at the home base; v = velocity, and c = the speed of light.

This theory has already been demonstrated with a subatomic particle called a mu meson (or Muon). On Earth, a muon has a very short lifetime; 2.2 millionths of a second. However - those muons that are a part of cosmic rays and are generated at the top of the atmosphere survive long enough to reach the Earth's surface, for they have been measured there. Their time is slower than ours and therefore their lifetimes, relative to us, are prolonged. The same could conceivably happen to a human. In short -

> "Aboard a relativistic interstellar spaceship, not only would the passenger's clocks move more slowly than their counterparts on Earth, but they themselves would move more slowly, their hearts would beat more slowly, their awareness of the passage of time would be retarded." (Shklovski & Sagan, 1966, p. 132)

Extraterrestrial Life: What Characteristics?

What types of intelligent beings might we expect to find on other planets in the universe? Will they be warlike; peaceful, tyrannical; benevolent? Will they look like homo sapiens? How will they act?

Regarding physical characteristics, even the most respected science fiction writers tend to give extraterrestrial aliens the same general characteristics as humans. This appears somewhat chauvanistic. Why, for example, on a planet with more or less gravity than Earth, ammonia instead of water, and hotter

or colder temperatures, would creatures be expected to resemble Earth inhabitants in any way?

An imaginative description of neighboring aliens has been offered by Dr. Ronald Bracewell. He suggests that if a planet has three times the gravity of Earth, lizard-like creatures might hold the advantage.

> "Instead of an arboreal ancestry, such creatures may have found their antecedents in swamps, where gravity could be counterbalanced by buoyancy and then, instead of taking to the plains and becoming upright walkers, as our ancestors did, they might move out from their place of genesis along waterways, natural and artificial." (Bracewell, 1974, p. 34)

Another possibility is that mechanical life might be found on an extra-terrestrial planet. For example - another race may decide to develop automated replicas or representations of themselves to carry on after their civilization becomes extinct. Or - automata could be developed as servants of a biological race and advance to the point where they no longer need their progenitors and journey out into space, creating civilizations of their own. Both of these conditions would increase the possible numbers of extant civilizations possessing interest and the capability for interstellar communication.

MacGowan and Ordway list a series of advantageous dimensions automata would have over biological life. Memory banks could be programmed with information that would take a lifetime for a biological specimen to acquire. Maintainability is another positive factor, for the automata should be able to exist indefinitely with only minor repairs.

> "A more impressive attribute....would be control of their own growth. Not only would it be possible for an automata to direct the production of its own replacement parts, but it could also design the production of additional components for its own growth.
>
> "An automation could easily control its own evolution as well as growth by gradually incorporating new technological developments. New technology could be incorporated by removing one major module at a time and either replacing it with a more advanced module, or modifying it so as to assimilate the new technology."
>
> (MacGowan & Ordway, 1960, p. 57)

They conclude that "most" societies with which Earth might communicate would probably be directed by automata. And-according to them, with unlimited lifespans they would also be more likely candidates for interstellar travel.

Obviously, any discussion of what social attitudes aliens might have, or their intentions towards Earth, is quite speculative. It is as speculative as attempting to describe the physical characteristics of such aliens, since we have only ourselves as models. Since their history is apt to be vastly different than ours, we are unlikely to have very much in common.

> "The most obvious and basic of the cultural and political factors is the inevitable difference of historical experience. The alien's cultural frame of reference, codes of behavior, and styles of social interaction will be different from ours. Only at the most basic and generalized level are we likely to be on common ground; (i.e., a concern for one's own security being an example). (Michaud, 1972, p. 23)

Whether or not they are peaceful in their own society may not reflect on how they would act toward another race. For example - prior experience may have taught them to travel through space prepared for military action, precipitated by their experience with other beings they find.

Not surprisingly, the consequences of making contact with another civilization is a subject treated with widely varying opinions. It seems equally plausible that an alien race would either want to conquer Earth and use it for some undetermined purpose, or to have a peaceful, mutually beneficial relationship. There is no way to make a definitive judgement on an issue such as this. As a case in point, three diverse views follow:

> "Thus, Philip Morrison, (a physicist at MIT) in one of his lectures, questioned whether any civilization with superior technology would wish to do harm to one that has just entered the community of intelligence. If we were looking through a microscope, he said, and saw a group of bacteria spell out, like a college band - "Please do not put iodine on this plate. We want to talk to you", his first inclination, he said, would certainly not be to rush the bacteria into the sterilizer." (Sullivan, 1973, p. 43)

"Aliens from other solar systems are a potential threat to us, and we are a potential threat to them. Scientists, and others, have often postulated that extraterrestrial societies more advanced than ours would be less warlike. Regrettably, the sterotype of the benevolent, superintelligent alien may be as unreasonable as the stereotype of the bug-eyed monsters carrying off shapely human females. Even if a species had achieved true peace within its own ranks, it would still be worrying about us, and would take the measures it felt were necessary to project itself. This includes the possibility, (not the inevitability), of military action. ....Our basic interest will be to protect ourselves from any possible threat to Earth's security. Our second concern would be to assist in developing, or to participate in, a stable system of interstellar politics that provides an acceptable level of security for us. Our third concern would be to learn from the aliens in order to advance our knowledge of the universe and to add to the tools of civilization. The last interest, so often placed first by writers on this subject, would be meaningless or impossible if the first two concerns had not been satisfied."

(Michaud, 1973, p. 76)

"Therefore, the only immediate effect on human society of the establishment of communications with extrasolar communities would be the sudden acquisition of very advanced scientific knowledge. ....No immediate change in human society could be expected to result from this vast accumulation of advanced scientific knowledge. The effect would be to accelerate the inevitable trends of social evolution of our biological society."

(MacGowan & Ordway, 1966, p. 29)

Although these various dimensions are factors which should be taken into account when deciding on how vigorously to pursue a program of interstellar communication, one must remember that our presence could not be detected out to some 50 light-years, as previously noted. The decision is, then, whether to sit passively by and wait for others to find us, or whether we should take the initiative. The Soviet Union, at least, seems to have opted for the latter.

A 1960 report for the National Aeronautics and Space Administration studies the possible consequences of contact and suggested its own research directions:

"Anthropological files contain many examples of societies sure of their places in the universe, which have disintegrated when they have had to associate with previously different ideas and different life ways. .....

Since intelligent life might be discovered at any time .... two research areas can be recommended:

1- continue studies to determine emotional and intellectual understanding and attitudes - and successive alterations of them, if any - regarding the possibility and consequences of discovering intelligent extraterrestrial life.
2- historical and empirical studies of the behavior of peoples and their leaders when confronted with dramatic and unfamiliar events or social pressures."

(Sullivan, 1973, p. 82)

As Smith concludes: "Considering reactions people have had to UFOs and Orson Welles' reading of War of the Worlds over the radio, such advice seems sound." (Smith, 1977, p. 119)

THE CONVENTIONAL WISDOM: WE ARE NOT ALONE

"The idea that we humans are not the only intelligent being inhabiting the universe is not a new one. John Milton speculated that the stars might be inhabited. Science fiction writers from Jules Verne to Isaac Asimov have imagined all sorts of improbable extraterrestrials to add spice to their stories. ..... No - the existence of nonhuman extraterrestrials is hardly a revolutionary idea these days. What may be revolutionary, however, is that over the past twenty years scientists have come to accept this notion, first tentatively, and now almost as an article of faith. Indeed .... estimates of the number of different civilizations in our galaxy alone run to upwards of a million. Like a drop of pool water, our seemingly cold and lifeless universe should, upon closer examination, seem to be teeming with life." (Rood & Trefil, 1981, pp. 1 & 2)

"Conventional wisdom holds that stars suitable for the origin of life are common, and the planets in which life has arisen are far from rare. This viewpoint is quite in keeping with the past five centuries of Copernicanism in astronomy, which have steadily removed mankind farther and farther from the center of things.

"However - in recent years a contrary view has surfaced. This view holds that far from being a commonplace in the galaxy, life such as ours has resulted from a most improbable concentration of events. If we then are not at the center of things, at least we may have the pleasure of contemplating that only by rare accident have we been fortunate enough to evolve; that one could search hundreds of thousands of years without finding our like. Yet life need not be tied to the planets where it arises. Intelligent cultures, by inventing the arts of space colonization and star flights, can make this pressure felt on a galactic scale.

"We thus are led to think about space colonization."
(Heppinheimer, 1979, p. 38)

"On January 2, 1902, we know from Robert E. Goddard's notebook, he wrote an essay on "The Habitability of Other Worlds". ....In it, we discover that Goddard was attracted but cautious about the possibility of life on Mars, certain of the existence of extrasolar planetary systems, and deduced that among these countless planets there are conditions of heat and light equivalent to those we experience; and if this is the case, and the planet is near our age and size, 'there may very well exist human beings like ourselves, probably with strange costumes and still stranger manners'. But he also says: 'it is for the distant future to answer if we will ever realize truth from our surmises.'" (Sagan, 1979, p. 39)

"By reasonable and conservative estimates and assumptions, we can conclude that the universe may be incredibly rich in intelligence. Along with our own, 390 million sets of companions in the great adventure of learning and speculating, have entered into civilizations right here in our own galaxy.

"It is possible to calculate the distance between two neighboring civilizations at about - on the average - 40 light years. That is not very great, as cosmic distances go.

"But then this question looms: Where <u>is</u> everybody? ....If we can't find any reason to deny the development of hundreds of millions of civilizations in our own galaxy, why is everything so quiet? Why has not one of them made itself known to us. The answer may lie in the fact that so far only so many civilizations have come into being. .....

"Our own civilization has a dubious future and if we can express the reason in brief it is that we find it difficult, (perhaps impossible), to cooperate in solving our problems. We are too contentious a species and apparently find our local quarrels to be more important than our overall survival. .....

"Homo sapiens has, it would seem, run the full gamut and now faces a situation whereby a full-scale thermoneuclear war could end civilization - perhaps forever.

"Let us, further, take ourselves as average and say that on every habitable planet with a total potential life-bearing duration of 12 billion years, an intelligent species comes into being after 4.6 billion years, and, in the course of 600,000 years, builds a civilization slowly and ends it quickly - ruining the planet, in the process, to the point where no further civilization can arise upon it.

"Since 600,000 is 1/20,000 of 12 billion, we can divide the 650 million habitable planets in our galaxy by 20,000 and find that only 32,500 of them would be in that 600,000-year period in which a species the intellectual equivalent of Homo sapiens is expanding in power. ....

"We can suppose that 540 habitable planets bear an intelligent species that, at least in the more advanced parts of the planet, are practicing agriculture and living in cities.

"In 270 planets in our galaxy, intelligent species have developed writing; in 20 planets modern science has developed; in 10 the equivalent of the Industrial Revolution has taken place; and in 2 - (only 2!) - has nuclear energy been developed. And these two civilizations are, of course, near extinction. ...

"On about 325 million such planets are signs of civilizations in ruins, in the range of a century to several billion years before. ....

"If all this is so, then even though our earlier analysis of hundreds of millions of civilizations arising in our galaxy is correct, it is no small

wonder that we haven't heard from them. " (Asimov, 1969, pp 192,193)

The publication of a paper entitled "Searching for Interstellar Communications" on 19 September 1939 in the British journal Nature was probably the turning point in the thinking within the scientific community about ETI. The authors of the paper were Philip Morrison (currently at MIT, Massachusetts Institute of Technology), and Giuseppe Cocconi of the Centre Européan de la Recherche Nucléaire in Geneva, Switzerland.

"In their paper the two combined their talents to present arguments to the effect that if there were advanced technological civilizations in the galaxy that wished to communicate with us (or other emerging societies), they would probably do so by sending radio signals at the wavelength of the most ubiquitous signal in the universe, that of the natural radiation of atomic hydrogen - the 21 cm line of hydrogen. ....their paper, in effect, put the scientific community on notice that it had become possible to search for ETI rather than just speculate about it. " (Rood & Trefil, 1981, pp 2, 3)

At about the same time this paper was published, astronomer Frank Drake in Green Bank, West Virginia, was having similar thoughts and so in the spring of 1960, in a project named for the fabled land of Oz (Project Ozma), ..."humans made their first conscious effort to detect the presence of other life forms. Using one of the first demonstration models of a new type of electronic amplifier, Drake and his group at Green Bank turned the telescope toward the nearby solar-type star Tau Ceti.

"The telescope revealed no signals that could be interpreted as evidence for ETI either on the first day or any other day of the three-month period during which the search was conducted. ....

"Since 1960, other searches for ETI have been made. All of them, like Project Ozma, have given a negative result. No evidence for ETI has been seen in any astronomical measure to date." (Rood & Trefil, 1981, p. 3)

Within the scientific community considerable excitement was being generated by the then-new ideas being published on ETI. This in turn led to a conference at the Green Bank Observatory in November 1961. Its intellectual impact was substantial. It .... "laid the intellectual groundwork on which virtually all subsequent work on ETI has been based. The most important and widely quoted results of the conference was an estimate of the number of communicating civilizations in the galaxy, an estimate that, on the more optimistic side put this number in the hundreds of millions." (Rood & Trefil, 1981, p. 4)

"Alien civilizations with the technological know-how to achieve interstellar travel exist somewhere among the trillion stars of our galaxy. If these societies at all resemble our own, they may leave electromagnetic footprints in the sky: radio, television and other transmissions falling within the range of earth-based telescopes.

"Detecting signals from alien civilizations is like looking for the proverbial needle in the cosmic haystack. Scientists have already devised ingenious ways to search for millions of possible frequencies. ....Carl Sagan suggests that water-based forms of extraterrestrial life might communicate at water frequencies, ammonia-based life at ammonia frequencies, and so on.

"The search for extraterrestrial intelligence (SETI) seems to be moving into high gear. Still .... I am uneasy. SETI haven't paid enough attention to crucial social decisions that aliens may have made, decisions drastically affecting our ability to detect the existence of these civilizations. ....

"Some scientists estimate that our galaxy consists of roughly 130 billion solar systems and that interstellar distances are so great that each of these solar systems is thousands of light-years away from most others. ....That means the time lag for messages, commercial transmissions and trips between most member stars of a galactic federation would exceed the length of recorded human history. (underlining supplied)

"Einstein's theory of relativity provides a loophole for galaxy-model civilizations. This loophole is time dilation, the slowing down of time as

spaceships - or any other objects - approaches the speed of light. ....at speeds close to 99 percent of the speed of light, time-dilation effects are dramatic. ....

"Time-dilation ....affects speeding spacecraft. At 99.00000 percent of the velocity of light, passengers will experience a 7,800 light-year trip to the Crab nebula and back as a three-and-a-half year jaunt. Unfortunately, there's one catch: from the perspective of those left on earth, the round trip will take 7,800 years; Einstein'an time-dilation only affects travelers. But societies could deliberately imitate Einstein by changing the relationship between subjective time and physical time for nontravelers too. .... advanced alien civilizations may decide to slow down subjective individual and social time.

"Let us call this sociological strategy social-time dilation. ....alien minds and bodies may be adapted (or built) to function thousands of times more slowly than bodies evolved naturally. When the individual and societies live in slow motion, the speed-of-light barrier loses its sting.

"Slowing subjective perceptions of time by a factor of 100,000 - for example, transforms a 1,000 year communications delay into a socially acceptable 5-day wait. Social-time dilation makes a galaxy-wide civilization possible, for no society need be more than a few subjective weeks or months away from the rest of the galaxy's inhabited planets, moons, asteroids and space stations. ....

"Have radio astronomers already detected signals from slow-motion super-civilizations without realizing it? The possibility is real. Scientists searching the heavens are expecting to find alien broadcasts beaming information at human or faster-than-human rates. And if they are looking for the extra-terrestrial equivalent of the Morse code blasting out at 20 words a minute, they might miss a transmission 100,000 times slower.

"To catch even the briefest scrap of slow-motion transmission, we may have to monitor the sky continuously for at least a year or two, then analyze the data gathered, searching for telltale patterns of ultraslow communication." (Gliedman, 1981, pp 16 & 114)

"New discoveries by radio astronomers
confirm our links to all matter that
exists throughout Darwin's Universe."

"The molecules that make up life are scattered throughout the cosmos like seeds on a freshly plowed field. Radio astronomers have recently discovered water, carbon monoxide, ethyl alcohol and even precursors of the simple **amino acid glycine drifting in clouds of interstellar dust. We now know that** the Universe is a vast chemical laboratory and that it may be devoted to the creation of life. And since the raw materials of life are the same everywhere, evolution is likely to follow parallel paths throughout the cosmos. It is Darwin's Universe. Astronomers estimate that there are 1.6 billion stars with planets in our galaxy alone; among the 100 billion detectable galaxies in Darwin's Universe, the opportunities for life are boundless.

"Scientists and nonscientists alike argued that extraterrestrial life won't resemble any familiar organism or machine because it will have evolved in environments far different from Earth's. But the new information supplied by radio astronomy - that the basic building blocks of life are the same everywhere - suggests that throughout the cosmos the dictates of the environment will be surprisingly similar.

"The family resemblance between us and our cosmic cousins starts at an invisible and profound level; that of atoms and molecules. The four basic elements of life - carbon, hydrogen, oxygen and nitrogen - are among the most abundant in the Universe and exist everywhere in about the same proportion.

"At the center of life on Earth - and elsewhere, radio astronomers now confirm - is the carbon molecule. Carbon has four electrons in its outer shell, which can be joined by four others. This symmetry allows carbon atoms to combine easily with others and form the long polymer chains necessary for life. ....

"But the existence of a planet exactly duplicating Earth - in size, rate of rotation, precise distance from the sun, inclination of its axis - is as unlikely as the existence of an evolutionary double for mankind. Changing just

a few physical parameters of a planet would lead to profound differences in appearance and indiginous life form. ....

"For a detailed model of how life can evolve on other planets, we need only look to Earth. On isolated continents thousands of miles apart, in environments that differ sharply from one another, evolution created three kinds of wolf, (two marsupial and the other placental), from ancestral shrewlike animals only distantly related. ....

"We can't expect exact duplicates of man and other earthly beings, however, because, as Harvard paleontologist George Gaylor Simpson and others have argued persuasively, evolution is nonrepeatable and irreversible. If life were to start all over again on a primitive Earth, neither man or other animals would evolve into their exact present forms. Our existence is the result of too many unpredictable events - climatic changes, solar and cosmic radiation, the fortuitous development of lungs in Paeleozoic fish gasping for air in shallow ponds.

"Earth's million-plus living species and its 250,000 or so fossil species represent only a fraction of life forms that have - or could have - lived on the planet. Known rates of evolutionary turnover have allowed experts to predict that the number of species that ought to be in our fossil record is at least one hundred times the number found so far. That adds up to 25 million species on Earth alone. Multiplicity by the billions of potentially life-bearing planets circling other suns, and the total possible number of cosmic species staggers the imagination." (Bylinsky, 1981, pp. 32, 34, 35, 36, 39)

"In considering the possible existence of extraterrestrial life, we have become accustomed to thinking of it chiefly in the context of our solar system. Yet in recent years information has accumulated that suggests, by some estimates of probability, that forms of life could be broadly distributed throughout the galaxy. It is within the realms of possibility, in fact likely, that

technically advanced civilizations may exist on the planets of distant stars. Communications with such far-off islands of intelligence may someday be begun, with effects on Man's home planet that can now be only imperfectly imagined. ....

" A short passage from a recent report of the Astronomy Survey Committee of the august National Academy of Sciences of the United States, the nation's most distinguished scientific body, gives an example of the modern attitudes:

> Each passing year has been our estimates of the probability of life in space increase, along with our capabilities of detecting it. More and more scientists feel that contact with other civilizations is no longer something beyond our dreams but a natural event in the history of mankind that will perhaps occur within the lifetime of many of us. The promise is now too great, either to turn away from it or to wait longer before devoting major resources to a search for other intelligent beings. ....In the long run this may be one of science's most important and most profound contributions to mankind and to our civilization.

"The critical point about the search (for extraterrestrial civilizations) is that human technology has now reached the point where we could detect ourselves at enormous distances away. ....Suppose we took the world's largest steerable radio telescope - Cornell's dish at Arecibo, P. R. - ....and imagine it in connection with an identical copy of itself. ....How far apart are they when they cannot make each other out anymore? The answer is that two such telescopes could talk to each other <u>from anywhere within the galaxy</u>; (underlining supplied) - our present technology is able to detect ourselves anywhere in the galaxy of 250 billion stars. ....

"The most optimistic estimates in the view of many, about the number of civilizations that might be in the galaxy, is on the order of a million, which means that only one in roughly 200,000 stars has such a civilization. Therefore, search requires not a brief look but some substantial, long-term commitment of radio-telescope time." (Berendsen, 1973; Carl Sagan's remarks, pp 8 & 11)

"I think there is no question but that we live in an inhabited universe that has life all over it. ....

"As for our own galaxy, it is estimated that perhaps 1 to 5 percent of the stars in it could provide on one or more of their planets an abode for life.

That would mean 1 billion such places just in our own galaxy that might contain life. And as for what life would mean in those places, I think it would mean something very like the life we know. Not the same creatures. We did not have the same creatures on Earth during the past as live here now. But life anywhere in the universe, I have been convinced for years, must be made of the same elements that principally constitute it here - carbon, hydrogen, nitrogen and oxygen.

"I believe that we living things on Earth constitute the only life in the solar system. ....The chance of breaking out of the solar system and establishing physical contact - or the chance of any creature in outer space establishing physical contact with us, coming to us from another solar system, seems so remote as to be almost nil. In order to do that, one would have to travel at the speed of light and it is rather hard to travel at the speed of light and not be light. So I rather doubt that physical contact is possible." (Berendsen, 1973; George Wald's remarks, pp 15 & 16)

At the previously mentioned Green Bank conference, the simple equation developed, which resulted in estimates of communicating civilizations in our galaxy, claims to allow for the calculation of an estimated number. "The equation is written:

$$N = Rf_p n_c f_l f_i f_c L$$

and each component noted represents the following:

N = number of advanced communicating civilizations in the galaxy

R = the rate at which stars are formed in our galaxy per year

f_p = the fraction of stars that, once formed, will have planets

n_c = the number of planets (per planet-bearing star) that will have environments suitable for life

f_l = the probability that this life will develop on such a planet

f_i = the probability that this life will evolve to an intelligent state

f_c = the probability that this intelligent life will develop a culture capable of communicating over interstellar distances, and

L = the time (in years) that such a culture will spend actually trying to communicate" (Rood & Trefil, 1981, p. 4

As professors Rood and Trefil note - arriving at sound estimates is extremely difficult. The problem is that currently we know little about some of the processes whose probabilities are to be estimated to 'plug' into the Green Bank equation. To help resolve this dilemma - "recourse is taken to a general philosophical assumption, usually called the 'assumption of mediocrity'. We shall state this assumption as follows:

> There is nothing special about the solar system or the planet earth.

In other words, we have to assume the rest of the universe is pretty much like our own neighborhood. Since we know a fair amount about the earth and its near neighbors, we can then proceed to put numbers into the Green Bank equation." (Rood & Trefil, 1981, pp 4 & 5)

Following is the now-usually, so-called "conventional wisdom" method for estimating the frequency of ETI. We know a fair amount about the formation of stars and planets, the first two terms in the equation; (i.e., R and f_p). A rough approximation results from dividing the approximate number of stars in our galaxy (10^{10} stars, or 100 billion) by the approximate age of the galaxy (10^{10} years, or 100 billion years). The equation then is:

$$R = \frac{10^{10} \text{ stars}}{10^{10} \text{ years}} = 1 \text{ star/year}$$

Rood & Trefil suggest that this may be a low estimate since in the earlier history of our galaxy, star formation probably occurred at a more rapid rate. They indicate that estimates for "R" range between 1 and 10 stars/year.

The process of star formation is but poorly understood. In part this results from the fact that currently our solar system is the only planetary system we can examine. Estimates for f_p (the fraction of stars that, once formed, will have planets), according to "conventional wisdom" range from 0.4 (i.e., somewhat less than half the stars have planets), to 1 (i.e., each star has a planetary system.

Moving along, assigning numbers to the other elements in the equation becomes more and more subjective. As a consequence, the 'assumption of mediocrity' (i.e., there is nothing special about the solar system or the planet earth), plays a greater and greater role in these 'guesstimates'. For our own solar system we know that n_e (i.e., the number of planets per planet-bearing star that will have environments suitable for life), is at least 1 - the earth! At the time of the Green Bank conference, some expressed the view that life quite probably could exist on Mars. (The space probe which later landed on Mars and sampled/analyzed its surface yielded inconclusive and ambiguous findings as to the existence of life). If the Mars space probe had yielded unambiguous, 'positive' results that some form of life existed on the planet, this would mean that $n_e = 2$. In general, values of an n_e between 1 and 5 are considered 'reasonable'; i.e., the probability that life will develop on such a planet.

Regarding f_l, by applying the assumption of mediocrity once again, such probability of actually developing life is considered to be 1, the earth! It is further assumed that <u>every</u> planet capable of developing life does so. Here again, applying the mediocrity assumption, f_i, the probability that this life will evolve to an intelligent state yields a numerical value of 1.

As for f_c, the probability that this intelligent life will develop a culture capable of communication over interstellar distances, tenuous 'evidence' from human history suggests f_c values ranging between 0.1 and 0.2. The reasoning for this conclusion is that there have been five to ten major civilizations in mankind's history - the 5 to 10 range reflecting the manner in which the counting of civilization is done. Only one of these - the Western European - has developed the nuclear energy capability.

The final element in the equation, "L", which represents the time-in-years that such a culture will spend actually trying to communicate; applying the mediocrity assumption leads to the conclusion that this numerical value must

be at least 100 years - our current time-span since our first radio transmission.

"Assuming that the civilization continues to survive and remains interested long enough, it could continue on up to the natural limits on civilizations lifetimes. The generally accepted limit is 10^8 to 10^9 years, the time during which a star remains relatively stable and capable of supporting life." (Rood & Trefil, 1981, p. 6)

Having accounted for; i. e. 'guesstimated' each element in the Green Bank equation, it is therefor possible to estimate the number of civilizations now presumed to be trying to communicate with us. Applying a three-track scenario approach to solving the Green Bank equation, ..."the three estimates for "N" .... as they are conventionally given are as follows:

Scenario	R	f_p	n_c	f_l	f_i	f_c	L	N
optimistic	10	1.0	1	1	1	0.2	10^8	2×10^8
conserv't'v	1	0.5	1	1	1	0.2	10^6	10^6
pess'm'stic	1	0.4	1	1	1	0.1	10^2	4

....we see that even within the conventional approach to the equation, it is possible to generate estimates of the number of communicating civilizations ranging anywhere from 200 million to less than 10" (Rood & Trefil, 1981, pp 6 & 7)

The significant fact to be noted in the above 3-scenario scheme is that conventionally the 'N' can be quite small. "In fact, given the uncertainties in all of the above probabilities, the answer N = 4 is completely consistent with the answer N = 1. Since we already know of one civilization that meets the requirements of the equation, (our own), a result of N = 1 would imply that no other communicating life exists in this galaxy. Even within the conventional wisdom, then, we could be alone." (Rood & Trefil, 1981, p. 7)

To date, SETI discussions have been substantially weighted toward the "optimistic" scenario option. For an N = 10^8, this yields an average-miles-distance between communicating civilizations of a mind-boggling mileage number,

simply because this distance is estimated to be 10 light years, (i.e., the distance in miles that light travels in a year's time, moving at the rate of 186,000 miles/second!). This mileage figure is 58 quadrillion, 400 trillion miles; a universe-large number!

Light traveling at the fantastic rate of 186,000 miles/second has traveled the following approximate miles in the time-span periods indicated:

1 light-day = 16 billion!

1 light-year = 5 quadrillion, 840 billion!!

10 light-years = 58 quadrillion, 400 billion!!!

"For reference, the following is a table of distances between civilizations for different values of 'N':

N	D
10^8	10
10^7	100
10^5	1,000
10^3	10,000
1	∞

N = number of advanced communicating civilizations

D = Light years

A glance at the table shows that even for fairly optimistic estimates of N, the galaxy is so large that civilizations will be isolated from each other by huge distances. This is one reason the scientists at Green Bank considered that even though communications between ETIs is plausible, visitation is not." (Rood & Trefil, 1981, p. 7)

In this country, since 1961, numerical estimates such as the three options presented in the above-3-scenarios table have been employed in an effort to justify the belief that there is a reasonable chance of success of an SETI. Although congressional action on appropriations has been sought, thus far it has been entirely without success.

"In the two decades since 1961, however, a great deal of knowledge has

been gained about planetary processes; the formation of life; and other factors that effect the estimates of the number of advanced civilizations. Individual authors have pointed out the significance of their findings to the question of ETI, but much of this work has been published in places not readily accessible to the public. The general effect of our new knowledge is to reduce considerably the estimates of the number of advanced civilizations, although - of course - large uncertainties remain in the final numbers....due to our present lack of hard facts regarding some of the elements comprising the Green Bank equation. In essence, we shall agree that our present understanding of the processes involved in the Green Bank equation even makes the conventional 'conservative' value of N overly optimistic and gives credence to the view that we might be alone." (Rood & Trefil, 1981, p. 8)

THE STARS: COSMIC SUNS

Stars are, in fact, distant suns. Confirmation of this fact awaited the first direct measurement of stellar distances in the mid-nineteenth century. In the scientific revolution started by Sir Isaac Newton, he maintained that the stars and other celestial bodies were governed by the same physical laws governing matter on earth.

Of the several thousand stars visible to human sight, very few are promising 'candidates' for supporting planets harboring intelligent life. The most prominent 'candidate' is Tau Ceti which is to be found in the southwestern sky, (as seen from the North Temperate zone). It is the nineteenth brightest star in the constellation Cetus. Scientists believe it is a better prospect for ETI than other brighter and more familiar stars to be seen nightly.

Our sun - a star - will, in about 5 billion years from now, exhaust (consume) the hydrogen at its core. Thereafter, in a few hundred million years, it will increase its luminosity to a few thousand times its present 'brightness'. At that time its radius will be more than 100 times greater than now. The planet

Venus will be incinerated within the sun and the Earth will be burned to a crisp. The sun's temperature, photospheric, will drop and the sun will become what is called a red giant. "At an age of about 10 billion years, the sun will have ended its life as an energy producer. Such a star is called a white dwarf. The final ejection of mass produces a planetary nebula, the result of a relatively mild, (as these things go), stellar explosion.

"The fact that intrinsically luminous objects tend to be those that are 'seen' introduces an observational bias .... (and) extremely luminous stars cannot support life in their systems. It follows quite simply that most of the familiar stars - the ones most easily seen - tend to be poor candidates for ETI." (Rood & Trefil, 1981, pp 19 & 20)

Today, it is accepted that our bodies are about 92% stardust plus 8% hydrogen surviving from the beginning of the universe - the so-called Big Bang. Most of the elements needed to form life were, if current ideas are correct, created in the few catastrophic minutes of supernova explosions.

"From .... our knowledge of the internal workings of stars, two important points for the development of ETI emerge. The first of these is that very heavy stars, because of their short life, could not serve as a basis for living systems. The second is that very old stars, because they were formed at a time before a great deal of heavy element production had taken place, could not do so either." (Rood & Trefil, 1981, pp 27, 28)

The above-cited restriction, cited by professors Rood and Trefil, regarding the home stars of intelligent beings, does not essentially modify the Green Bank equation. These two life-exclusion groups among stars, together represent roughly 1% of the stars in our Milky Way galaxy. This does not seriously alter the conventional wisdom, three-option estimates of the number of advanced communication civilizations in the galaxy; i. e., 'N' in the Green Bank equation.

The Planets

Currently the only planetary system we are able to investigate, or even hope to do so, is our own. On-going debate still continues whether any extra-solar system has even been detected, let alone studied. The one possible exception is Barnard's Star. Direct visual detection of planets is difficult because of the fact that planets reflect only a small amount of the total light of the star. However, it may be possible to detect planets beyond our solar system indirectly from earth. "At the moment, there is only one claim that a planet has been detected on a nearby star. .... Barnard's Star is a small (o.15 solar mass) star about 3 light years away. Since the late 1930s, Peter van de Kamp of Sproul Observatory at Swarthmore College, (now Edward Hicks Magill Professor Emeritus of Astronomy and Director Emeritus of the Sproul Observatory), has taken thousands of photographs of the star. .... Even though some controversy remains, van de Kamp and Lippencott seem to have successfully detected the first extra-solar system planet." (Rood & Trefil, 1981, pp 41, 42)

Consequences for SETI:

"From our knowledge of the way stars and planetary systems are formed, we can draw a number of important conclusions:

1- Binary stars close to each other probably do not possess planets at all. This rules out about two-thirds of the otherwise suitable stars as places where life might develop.

2- If we also exclude binary stars with large separations, we rule out 80 to 90 percent of the available stars.

3- If it should turn out that the special circumstances surrounding the birth of our solar system are important in the formation of planets, the probability of planets appearing in a given star system could be very small. There are at least two indications of such special circumstances. The sun may well be such a slow reactor because the initial angular momentum of the solar nebula was small, in which case our solar system may exist because there was less angular momentum to shed. A second reason could be that in the supernova-induced

solar system, the Aluminum injected in the nebula would be a substantial heat source in the first planetesimals, melting any that are larger than a few kilometers. This could greatly alter the early accretion of the terrestrial planets.

"In view of these conclusions, we can assign some values to the number f_p - (the probability that a planetary system will be formed) - in the Green Bank equation. We shall adopt the following:

Scenario	f_p
optimistic	0.3
conservative	0.1
pessimistic	vanishingly small

"We can expect concrete improvements in our knowledge of planet formation in the next few years. A modest investment of time and money should make the detection of planets like Jupiter in other systems possible in perhaps two decades. Coupled with our increased understanding of star formation and theoretical studies of planetary systems, f_p could easily become the best-known term in the Green Bank equation." (Rood & Trefil, 1981, pp 44, 45)

Life-sustaining Planetary Atmospheres:

Recent studies of the earth's climate have revealed the rather amazing fact that over the past 4 billion years, the sun has increased in brightness by 25%..."but during the same period of time the earth's atmosphere has changed in such a way as to keep temperatures at the earth's surface almost constant. As far as we can tell, the net effect of a number of massive changes in the composition of the earth's atmosphere and the changes in the sun has been a temperature at the earth's surface that has fluctuated by only about 200°C throughout this period. The word 'miraculous' is probably not too strong a description of this fact. It seems that very small deviations from the narrow path we have followed

could have led to the earth's being a fiery hell like Venus or a frozen wasteland." (Rood & Trevil, 1981, pp. 46, 47)

This narrow line between runaway glaciation and greenhouse effect seems to be part of the evolution of a planetary atmosphere. For example, it has been calculated by Michael Hart, now on the faculty of Trinity College in Texas ... "that if the earth's orbit were less than 95 percent of its present size, the earth would resemble Venus today. Similarly, if its orbit were only 1 percent bigger than it is, glaciers would have covered the earth for the past 2 billion years. Thus, it would appear that there is a very narrow band around the sun in which a planetary climate can avoid either of these two extremes over a period of several billion years. This band is called the continuously habitable zone (CHZ).....and "only planets in the CHZ of a star can be expected to support life." (Rood & Trefil, 1981, pp. 52, 53)

How large are these zones? "According to Hart's calculations, this fate (the planets freezing over and remaining frozen) will overtake <u>any</u> life-bearing planet circling a star whose mass is less than 83 percent of that of the sun. Such stars,in other words, have no CHZ at all. ....

"The CHZ of larger stars becomes bigger than that of the sun, but larger burn their fuel faster. Thus, even though larger stars may have ample numbers of planets in their CHZ, they burn up their fuel before life has had its requisite several billion years to develop. The calculations indicate that the stars whose masses exceed that of the sun by more than 20% will not last long enough to support life. ....

"The net results of (Hart's) calculations is that only stars very similar in type to the sun - the so-called G stars - can have planets that support life, and only if the planets happen to form in a fairly narrow band known as the continuous habitable zone. These results place important fundamental restrictions on the arguments for the existence of ETI.

"An equally important restriction can be placed on the size of the planet, regardless of the type of star it circles. Planets much larger than the Earth will produce more outgased material. Since this material includes carbon dioxide, the greenhouse effect will become stronger. Hart's calculations show that for a planet whose radius is 10 percent larger than that of the earth, the CMZ vanishes completely.

"It is also possible for a planet to be so small that it cannot generate enough atmostphere to block out the harmful ultraviolet radiation from the sun. .... This means that life on such a planet need never emerge from the sea, and thus that civilizations interested in interstellar communication will probably never develop. This will be the fate of planets whose radius is less than 94 percent that of earth." (Rood & Trefil, 1981, pp. 53, 54)

Recent Climate on Earth:

Intelligent life on earth is a 'recent' occurrence; i. e., during the past few million years. Recent climate developments have been relatively mild and seem to have been caused by the small periodic changes in the earth's orbit around the sun. The earth's axis undergoes a regular motion known as recession. In 10,000 years this will have moved the axis so that the Northern Hemisphere summer will occur when the earth is closer to the sun than it is in present summers. At this time the Northern Hemisphere summer will occur in January. It has therefore been suggested that the onset of glaciation occurs when Northern Hemisphere summers are cool, so part of the snow survives all year. In addition, the changes in solar input which drives the glaciers back and forth are very small.

Implications for ETI:

Two terms (i.e, estimates) in the Green Bank equation can be revised in the light of this knowledge of planetary atmosphere. The first estimate is the birth rate of stars; the 'R' in the equation. From Hart's calculations we now consider that only G stars - whose mass is near that of the sun - will have CHZs.

"Therefore, for R we must use the birth rate of G stars only, not just the birth rate of stars in general. Since only a few percent of all stars are in this category, the new estimate for R will be considerably below that used in our original analysis." (Rood & Trefil, 1981, p. 58)

Based on our knowledge of the stellar birthrate and distribution of stars in mass within the neighborhood, only about 4% are in the appropriate mass range. And their birthrate is an estimated 5 billion years ago. "Extending the solar neighborhood to the galaxy as a whole, models for galaxy evolution suggest that R = 0.05 stars/year. There is about a factor of 5 uncertainty from which we take the optimistic estimate. Because there is some evidence that the formation rate of G stars may have been much smaller previous to the formation of the sun, we adopt a factor of 10 reduction for the pessimistic value." .....

Thus the three scenarios are revised to the following values:

Scenario	R (G stars/year/galaxy)
optimistic	0.15
conservative	0.05
pessimistic	0.005" (Rood & Trefil, 1981, pp 58, 59)

The second estimate to revise is for n_c; i. e. the probability that there will be a suitable planet for the establishment of life. Here too, the revised estimate is much lower than the previous one suggested earlier. As has been noted, ..."The planetary size must be between 0.94 and 1.1. earth radii. Furthermore, it must be in a band width only perhaps 5 percent of the earth distance. ....

"We can get some estimate of n_c from our own solar system. There are two planets of the approximate size; Earth and Venus. Assume these are placed randomly within two earth-sun radii of the sun, there is a 2 to 3 percent likelihood for our planet to be in the continuously habitable zone. The probability of either one or the other being in the zone is about 5 percent. Models for planetary formation support these crude estimates. A reasonable estimate for the

number of suitable planets is thus $n_c = 0.005$. ....

Therefore, the three revised scenarios are:

Scenarios	n_c
optimistic	0.2 planets/star
conservative	0.05 planets/star
pessimistic	vanishing small" (Rood & Trefil, 1981, p. 59)

"The impact of climate upon the formation and evolution of life is," in the judgement of professors Rood and Trefil...."not just a coincidence that recurrent glaciations started at the time that humanoids first appeared. The birth of agriculture and the beginning of technology followed the last glaciation as the rainfall retreated northward along with the glaciers. Another coincidence? How will we and the world adjust to having Chicago, New York, and Boston under several thousand feet of ice in a few thousand years? An optimist might expect that such an occurrence would spur a major period of technical innovation." (Rood & Trefil, 1981, p. 60)

THE EVOLUTION OF LIFE

Moving from the chain of events leading to the formation of a star to the existence of an advanced technological civilization, the next step is the appearance of life in the star's planetary system. There has been and currently continues to be debate regarding the precise definition of the term 'life' and 'living system'. Despite the ongoing dialogue, we may not agree on a definition but yet we seem to believe we know it when we see it.

"Most biologists admit that the definition of life has been increasingly elusive since the days when a living object was tentatively described as one that did such things as eat, drink, metabolize, breathe, grow, reproduce and possibly move. 'All those old definitions don't really fit', says Carl Sagan. 'My automobile eats and breathes and metabolizes and moves. Crystals are grown and even reproduce.' .... He (Sagan) wrote the article under the heading of "Life" in the most recent Encyclopedia Brittanica, and it is probably the most lucid account

of current thinking on the subject. *In it he states that evolution by natural* selection is the feature that distinguishes living matter from non-living. Additionally, he has said: "There is no other foolproof way to get at the complexity of life, for most sociologists have come to the conclusion that the only certain thing they can say about life is that it is something that evolves." (Cooper, Jr., 1981, p. 62)

Where is the line between living and non-living? When we look out into space and insist upon interpreting cosmic processes as non-living phenomena, we are, perhaps, being too limited. It is not too great a step from acknowledging that the body is alive to accepting what researchers call the Gaia hypothesis, (named after the Greek earth goddess): the notion that the earth's biosphere plus its atmosphere equal a living entity. Within a protective membrane of atmosphere, earth's life forms and that atmosphere are continuously sharing chemical products - as do parts of the body - in order to maintain an ecological living balance.

"Can our planet be considered a living thing? Scientists seem to agree that all living systems reproduce and that they all use energy; they take in nutrients, process them, extract energy and excrete waste products. We can ... observe this process at work .... at the planetary level. The earth absorbs sunlight; a waste product, heat, is radiated out into space. This conversion of energy or substance from one form to another in order to maintain the functioning of the organism is its metabolism. The earth has a metabolism; it is alive. And if the earth is alive, why not the universe? ....

"Because we are so used to measuring living things in terms of decades or centuries, we balk at the idea of metabolic processes taking billions and billions of years....But the millenia of our time scales are simply ticks of the cosmic clock. ....What do you see? A cloud of hydrogen gas is sucked into a compact core and then transformed into heavier atoms, cooked by the nuclear blaze at the star's center. The heavier atoms are excreated in the form of stellar winds or a violent stellar explosion. Like other living things, stars reproduce, their waste products are fed

into other regions of space, when they become part of the new contracting clouds destined to become stars, within which energy will be exchanged and still more waste products excreted. Our speed-up view of what happens in space reveals constant evolution and movement. ....

"The nucleus of a galaxy can be likened to a heart. We know that it pumps plasma - hydrogen gas with some impurities ('Nutrients') - out into the surrounding 'veins', the spiral arm, streams of interplanetary hydrogen, that reach out and touch neighboring galaxies. And if our Universe is made up of living galaxies, is it then not alive? ....

"We must think seriously about relocating the line between living and non-living organisms. I no longer believe that it is at the edge of the body's epidermis or at the edge of the earth's atmosphere. It is at the edge of the Universe." (Verschur, 1981, p. 31)

Both the United States and the Russian space agencies have launched planetary probes landing on both Mars and Venus. To date, all evidence indicates that within our solar system life, as we recognize it, exists only on Earth. Therefore we have but our own example of evolution upon which to base conclusions regarding the probability of life existing elsewhere. What do we know about evolution of life on earth?

First - our own evolution development was relatively rapid. Second - our evolutionary development was not uniform, it ... 'Utilized a number of different mechanisms at different times." (Rood & Trefil, 1981, p. 62) Today we believe that the oldest minerals on earth are about 4.5 billion years old, suggesting the earth's age, in round numbers, of about 5 billion years. Earliest fossil evidence of life in sedimentary rocks indicates about 3.8 billion years. Further, this... "fossil evidence indicates that the evolutionary process was pretty far along by the time the earth had reached 25 percent of its present age." (Rood & Trefil, 1981, p. 62)

Our present complex and varied life forms did not all develop at one time; a number of steps can be identified which necessitates completion before complex life could evolve. These are:

"1. The formation of small organic molecules from the earth's original material.

2. The combination of these small molecules into the long chains necessary for living systems.

3. The formation of isolated, reproducing systems from these long molecules.

4. The formation of cells and multicellular organisms.

5. The evolution of the different species of plants and animals." (Rood and Trefil, 1981; p. 62)

The first three steps may be termed 'chemical evolution.' ...."Since they all involve various physical and chemical processes. The last two steps we can categorize as 'biological evolution' because they involve the development and competition between biological species." (Rood & Trefil, 1981, pp 62, 63)

From the point of view of ETI, the significant fact is that the first three 'chemical' steps evidently were strongly dependent on the environment in which they took place, whereas the last two 'biological' ones proceeded through natural selection processes.

"The picture that emerges of the earliest stage of chemical evolution is one in which organic molecules are found in the atmosphere by processes that can be duplicated in the laboratory. These molecules become a sort of organic 'rain', which enters the ocean, where their concentration builds up to the point where the next step in the evolutionary process could take place." (Rood & Trefil, 1981, pp. 67, 68)

"The only thing we know for certain about the evolutionary process is that by 3.8 billion years ago, simple cells capable of passing on characteristics to offspring existed on the earth. These cells carried their genetic material

spread throughout rather than in a nucleus as in advanced systems. Nevertheless, with their appearance the evolutionary process 'shifted gears' and new mechanisms came to the fore." (Rood & Trefil, 1981, p. 74)

Biological Evolution: Natural Selection

The crucial role played by natural selection in the development of advanced life forms on earth was recognized by the scientist Charles Darwin. He pointed out that for natural selection to function, two essential elements must be present. "First, there must be living systems capable of passing genetic materials; i. e., changes, on to their offspring, and second, there must be an environment in which different organisms have different chances of growing to maturity and reproducing. In a large population of a given type of organisms, random genetic changes will ensure that a few members of each generation will differ slightly from their fellows. If these differences are such that their carriers are more likely to live and reproduce, then the next generation will contain more members with the advantagous differences." (Rood & Trefil, 1981, pp 74, 75)

This process of differential selection is known as mutation. "On the microscopic scale, mutations arise from changes in the arrangement of molecules in the material in which genetic information is stored. On earth, a mutation would correspond to a random change in the DNA in a given cell." (Rood & Trefil, 1981, p. 77) In short - the mechanism of natural selection, given enough time, will result in the elimination of the old population and its replacement with one better suited to the environment.

The implications of natural selection, as far as ETI is concerned, is that it will operate on any system capable of reproduction and mutation. From what we know of life on earth, once the first reproducing system with genetic material comes into being the development of higher life forms will follow, naturally.

"For the first 2 billion years after life appeared on earth, (that is, until about 1.5 billion years ago), the selection processes acted on changes induced largely by (mutations). About this time, however, a new source of

variation arrived on the scene: sexual reproduction. Instead of simply splitting into two identical organisms, living systems that reproduce sexually create offspring whose genetic material is a mixture of that of the parents. In this way, a large number of different combinations of the parents' genetic material are possible. (Rood & Trefil, 1981, p. 79)

Implications for ETI

Applying the knowledge about the evolution of life on earth to the question of ETI, referring again to the Green Bank equation, the number f_l (i.e., the fraction of suitable planets on which life develops) can be written as follows:

$$f_l = f_m f_p f_i f_r f_c$$

These symbols have the following meanings:

f_m = the probability that simple organic molecules (monomers) will be produced.

f_p = the probability that polymerization will occur to produce large molecules.

f_i = the probability that polymers will form isolated systems.

f_r = the probability that these isolated systems will develop reproductive capacity, and

f_c = the probability that simple responding systems will develop into complex organisms. ....

From the fact that life did evolve on earth, we know that none of these probabilities can be zero." (Rood & Trefil, 1981, p. 80)

For f_m the best guess for this probability is $f_m = 1$. This is deduced based upon the results of laboratory experiments in which the formation of simple organic molecules and amino acids were created in .... "a reducing atmosphere with an energy source." (Rood & Trefil, 1981, p. 80)

For f_c the value of 1 is assigned based on the belief ....."it is virtually certain that once a single cell of cell-like object appears, the higher life forms will appear eventually." (Rood & Trefil, 1981, p. 80) This process of natural selection .... "seems to be such that once a simple responding system develops, complex forms will evolve as a matter of course." (Rood & Trefil, 1981, p. 80)

For f_i the value of 1 is assigned. This is predicated on the assumption that ...."once a concentrated solution of polymers is formed, the polymers will tend to isolate themselves from their surroundings according to simple physical principles." (Rood & Trefil, 1981, pp 80, 81)

Given our present level of knowledge, f_r - the probability that an isolated system of polymers will develop the ability to reproduce, cannot be evaluated. It could, for example, be anything from 1 (which would be a situation in which reproducing systems always develop), ..."to a number so small that this process could only take place on earth." (Rood & Trefil, 1981, p. 81) Therefore, for the three scenarios previously discussed, the following estimates are made:

Scenario	f_r
optimistic	1
conservative	0.1
pessimistic	virtually zero

For the value of f_p the probability that polymerization will occur to produce large molecules ...."whether or not the development of life stalls at the polymerization stage depends critically on the natural process responsible for the elimination of water from the organic mixtures in the early oceans." (Rood & Trefil, 1981, p. 83) From our present, incomplete knowledge, for the three scenarios the following estimates are made: "On the optimistic side, we could argue that it is possible that any of the four suggested processes could get us through the polymerization stage. In this case, we could assign a value of $f_p \approx \frac{1}{2}$ on the grounds that it shouldn't be too unlikely that one or the other will occur.

On the pessimistic side, we could argue that it is possible that a planet in a continuously habitable zone would have to possess a large satellite to create tidal pools. In this case, a value of $f_p \approx 10^{-4}$ would seem to be reasonable.

For our conservative estimate, we will take a value of $f_p = 0.1$, bearing in mind that this number could be (and probably is) at the upper end of the reasonable and conservative scale for f_p.

In summary, our three scenarios lead to the following estimates for f_1:

Scenarios	f_1
optimistic	0.5
conservative	10^{-2}
pessimistic	almost zero." (Rood & Trefil, 1981, p. 83)

Intelligence and the lifetime of a communicating civilization

The last terms in the Green Bank equation deal with:

f_c = the probability that this intelligent life will develop a culture capable of communicating over interstellar distances, and

L = the time (in years) that such a culture will spend in trying to communicate.

These two, perhaps, are the most difficult to quantify since they are topics about which we know so very little.

"The exact importance of intelligence in survival is something that is hard to assess, but it is clear that any race that is going to get into the game of extraterrestrial communication will have to have some sort of tool-making ability. We can assume, therefore, that they are intelligent. And although we cannot state with certainty what evolutionary steps must be taken in order to produce intelligent beings, we can certainly recognize a number of events that were important in this record for the human race: the following are the six events we feel are critical: .....

1. The development of an atmosphere containing oxygen. ....
2. The move to land. .....
3. The regulation of body temperature. ....
4. The development of hands and eyes. ....
5. The use of tools. ....
6. The development of social structure. ....

"Eighteen thousand years ago the changing climate conditions associated with glaciation gave a competitive edge to the beings with the best brains. In other words, there was a time for the process of natural selection to act. Since

the foundation of advanced societies, however, this is no longer the case. The 5,000 years that have elapsed since the start of recorded history have been a huge change in the human environment, but this is much too short a time for natural selection to have had a chance to act. We are facing the twentieth-century problems with ice-age minds, and the genesis of this problem is sufficiently general that we can imagine that other advanced life forms will face a similar dilemma." (Rood &Trefil, 1981, pp. 89, 90)

"As for the future of intelligence, we feel that the most likely path for the human race to take will be one in which our ice-age brain will be supplemented by computers in performing those tasks where supplementation is needed. We can imagine 'bionic' computers being implanted in the human body for this purpose, but there will probably be little change in our biological brains in the foreseeable future. If we use the assumption of mediocrity; (i.e., there is nothing special about the solar system or the planet earth), to draw conclusions from this fact, we see that any extraterrestrial race we are likely to encounter will probably also be equipped with their version of the ice-age mind. It is a situation with a fair level of danger to both sides." ....

"The fact that a civilization develops the ability to carry on interstellar communications is no guarantee that it will. ....

"It seems very likely that being involved in environments where the stars are not immediately available to the senses would be less likely to develop interest in astronomy and interstellar communication than would beings like ourselves. Thus, civilization developing on a planet with a thick cloud cover would be less likely to be sending signals to our receivers than we might think." (Rood & Trefil, 1981, pp. 96, 97) ....

"The last term in the Green Bank equation is the one about which we know the least. The number we have called L could be anywhere from 100 to 1 billion years, depending on how optimistic we want to be." (Rood & Trefil, 1981, p. 98)

Sebastian von Hoerner of the National Radio Astronomy Observatory in 1961 postulated possible routes that a civilization can take after the communicating stage is reached. These are:

"1. complete destruction, (for example - via nuclear war)

2. destruction of higher life forms only

3. degeneration of the civilization, and

4. loss of interest."

(The following table) ..."lists these four scenarios with von Hoerner's estimates of the length of communication time and the probability of each route being taken.

Route	L (years)	Probability
complete destruction	100	.05
destruction of higher life	30	.60
degeneration	30,000	.15
loss of interest	10,000	.20

"As von Hoerner himself points out, there is a measure of subjectivity in producing a set of numbers like this. For example, the high probability assigned to self-destruction is understandable in a paper written in the early 1960s, when the cold war was going strong. Modern authors might point to our success in avoiding nuclear destruction over the past two decades and assign a lower probability to these alternatives. (Rood & Trefil, 1981, p. 98)

Professors Rood & Trefil also note in their discussion of how long a civilization will continue to try to communicate, that simple statistical analysis gives us an average length of communication time to be 6,500 years, employing von Hoerner's estimates. In addition, they note that if we do make such contact .... "it will most likely be with a civilization that has been communicating for 12,000 years, with a 75% probability that the civilization will have regrown from an earlier culture that either degenerated or was destroyed." (Rood & Trefil, 1981;p.99)

Drs. Rood and Trefil conclude their discussion of "L" by proposing their own, as they note, ..."equally subjective estimates of the various probabilities. These are:

"Route	L (years)	Probability
complete destruction	100	.05
destruction of higher life	30	.20
degeneration	30,000	.35
loss of interest	10,000	.40" .....

"From this set of values, the same statistical analysis used by von Hoerner leads to a value of L = 14,500 years, with the first contacted civilization being 25,000 years old and a 55% probability of being 'regenerated'.

"it is possible, therefore, to make some sort of estimates of communication lifetimes, however tentative they may be." (Rood & Trefil, 1981, p. 99)

Significance of ETI

Summarizing the previous discussion, the three possible scenarios for an advanced civilization to develop intelligence, (i.e. "f_i"); develop technology, (i.e. "f_c"), and have a desire to communicate, (i.e., "f_d"), and the most likely time span for that communication, (i.e., "L"), are as follows:

Scenario	f_i	f_c	f_d	L (years)
optimistic	1	1	1	1,000,000
conservative	0.5	0.5	0.5	10,000
pessimistic	very small	very small	very small	100

SUMMARY

To recapitulate and summarize the Green Bank equation components "that play an important role in our estimates of the number of communicating civilizations in the galaxy, ... at the present time:

$$N = Rf_p n_c f_l f_i f_c f_d L"$$ (Rood & Trefil, 1981, p. 119)

To summarize:

N = number of communicating civilizations in the galaxy at the present time.

R = rate of star formation.

f_p = probability that a star will have a planet.

n_c = number of planets per star capable of supporting life.

f_l = probability that life will develop.

f_i = probability that intelligence will develop.

f_c = probability that a culture will develop the means to communicate; (i. e. technology)

f_d = probability that it will desire to do so, and

L = the time (in years) that the attempt at communication will last.

Initially it was noted that ...."N could be anything from one to a billion, depending on the assumptions that one made. ....however, we have seen that new knowledge has greatly reduced the freedom to choose any number we like for terms in the Green Bank equation. We are now in a position to put together what we have learned and come up with a new estimate of "N". (These are noted) "In Table 1." (Rood & Trefil, 1981, p. 120)

In the Legend immediately following Table 1, the parenthetical statements reflect .... "the major restrictions introduced by our understanding of nature. The results of Table 1 are then summarized in the values of "N" noted in Table 2. ..... For reference, we include in Table 2 the results of our preliminary analysis." Rood & Trefil, 1981, pp. 119, 120)

Table 1: Diverse Estimates: Green Bank Equation Probabilities@@

Probabilities	Equation Terms							
	R	f_p	n_c	l	i	f_c	f_d	L
Optimistic	0.15	0.3	0.2	0.5	1.0	1.0	1.0	10^6
Conservative	0.05	0.1	0.05	0.01	0.5	0.5	0.5	10^4
Pessimistic	0.005	vs ¢	vs	vs	vs	vs	0.5	10^2

@@ = Adapted from Rood & Trefil, 1981, p. 122

¢ = This 'vs' entry should be 'translated' to mean that the 'very small' number is so small that the Earth is the only planet supporting an advanced civilization.

Legend:

R = rate of star formation (Only G stars can have continuously habitable zone around them).

f_p = Planet formation. (Only single stars can have habitable planets; solar systems may form only near supernovae).

n_c = Habitable planets per star. (Only planets in the continuous habitable zone can develop advanced civilizations capable of communicating.)

f_l = Development of life. (The joining of amino acids into long chains may require special conditions, such as large moon.)

f_i = Development of intelligence. (The move to land may require tidal pools).

f_c = Development of communication technology. (The development of technology may require periodic ice ages or the equivalent.)

f_d = Desire to communicate. (Who knows another's desires?)

L = Length of communication time; in years. (A million years is the time typical of spaceship travel around the galaxy)

Table 2: Final Estimate of Advanced Communicating Civilizations ¢¢

Probabilities	Preliminary **	Final
Optimistic	2×10^8	5×10^3
Conservative	10^6	0.003
Pessimistic	4	very small @

¢¢ = Adapted from Rood & Trefil, 1981, p. 123.
** = Green Bank equation estimates prior to the subsequent knowledge discussed in this document.
@ = This entry should be 'translated' to mean that the probable number is so small that the Earth is the only planet supporting an advanced civilization.

"The 'Conservative' result in Table 2 gives the value of N as 0.003. This doesn't mean we feel that there is only 1/300 of a civilization in the galaxy. To interpret this result, we say that if we listen for communication from any place in the galaxy for a year, the chances are only 1 in 300 that we will hear anyone who is sending. Stated another way, if we counted the number of years since the formation of the galaxy that someone may have been communicating somewhere, we would find that the time during which signals were being sent out would be only 1/300 of the lifetime of the galaxy. ....

"It seems reasonable to suppose that as we learn more about the processes reported in the equation, we shall be able to see more places where things could go wrong, (i.e., more'bottlenecks'.) We predict, therefore, that during the next few decades the optimistic estimate for N will continue to drop as it has in the past few years." (Rood & Trefil, 1981, p. 125)

"One of the most obvious features of these two tables is that the revised estimates of the frequency of extraterrestrial intelligence are much lower than had previously been thought. In fact, the optimistic estimate that results from factoring our new knowledge into the Green Bank equation is a thousand times less than the conservative estimate that came out of the original Green Bank conference in 1961. It is literally true that everything we have learned in the past two decades has acted to decrease the possibility of making contact with other life forms." (underlining supplied) (Rood & Trefil, 1981, p. 120)

Regarding the evolution of communicating civilizations, professors Rood and Trefil suggest that this may be realistically considered to consist of a series of bottlenecks. Each bottleneck should be regarded as an obstacle to be overcome if the end desired (i.e., advanced communicating civilizations), is to be reached. The pessimistic scenario estimates in Tables 1 and 2 simply necessitate that any one of these bottlenecks be truly narrow. However, in order that the optimistic "N" result be achieved, all of these bottlenecks must be at maximum possible width to permit the next evolving step to occur.

In the evolution of advanced communicating civilizations these bottlenecks are:

1- G star?

2- Continuously habitable zone?

3- Polymerization and primitive life?

4- Intelligence?

5- Technology?

6- Communication?

"For example, if the optimistic numbers for G-star formation and the formation of planets turn out to be correct, but if the existence of tidal pools is necessary for the primordia; soup to form polymers, there could be many planets in the galaxy whose oceans will be full of amino acids, but none other than earth that have living systems. Similarly, if the optimistic numbers are

correct all the way up to "f_c", but if it requires special weather conditions like the ice age for intelligent life to develop technology, there will be many planets with intelligent life, but none trying to communicate with us.

"In developing the optimistic scenario, we have been very generous in giving the benefit of doubt. We feel, therefore, that it is extremely unlikely that all of these generous estimates will be correct. Consequently, our major conclusion from Table 2 is as follows:

> The total number of advanced civilizations in the galaxy is small, and there could well be only one."
> (Rood & Trefil, 1981, p. 121)

"Is the Earth Special After All?

Since the Copernican revolution, the main thrust of science has been to make the assumption of mediocrity seem more and more reasonable. The earth is not at all the center of the universe, but revolves around the sun. The sun is a single star in a galaxy of 10 billion stars, and the galaxy itself is only one of millions in the universe. Darwin showed us that humanity has been created in the same way as other animals, and Freud showed us that there is more of the primitive in our nature than we might have thought. It seems that the more we learn about ourselves, the less special we become.

"Now for the first time in five hundred years, things seem to be going the other way. During the past two decades, the more we have learned, the more we can see the earth as something special. For convenience, the following is a summary of the special features of the earth:

1- Earth is a planet in the system of a single G star.

2- It is the narrow band about that single G star where water will neither boil nor freeze for the billions of years necessary to produce life.

3- It has a large moon, which means that there are appreciable and variable tides, leading to numerous tidal pools.

4- The tilt of the earth's axis is just enough so that, in conjunction with the influence of the other planets, periodic changes in the climate occur.

"The significance of each of these points has already been discussed separately. The point we wish to make here is simply this: Although the probability of any one of these features being present on a planet may not be impossibly small, the probability that all four will be present at the same time is. So maybe the earth is special after all." (Rood & Trefil, 1981, pp. 123, 125)

SETI: The Search for Extraterrestrial Intelligence

"The best way to begin an inquiry into how to go about listening for signals from other worlds is to ask how we would go about sending signals ourselves. ....Any beings wanting to send signals will be beaming them into the same galaxy that we observe, and consequently they would come to approximately the same conclusions that we would about how to announce their presence. ....

"If we were to detect a message from ETI, would we be able to translate it? Considerable thought has been given to this problem. Frank Drake and Carl Sagan have shown how a great deal of information can be conveyed in a small number of bits by arranging them into a two-dimensional pictograph and relying on the listener to provide a reasonable interpretation." (Rood & Trefil, 1981, pp. 128 & 154)

"Today when the Earth is concerned with a soaring interchange of ideas, we are even trying to send our thoughts beyond our planet to other minds in the Universe. Our first efforts at sending our thoughts beyond Earth have taken a very ancient form: pictographs. ....

"All the accomplishments since humans first scribbled in the sand have led us back to where we began. Written language only works when two individuals know what the symbols mean. In interstellar communication, we are at the same stage our ancestors were when they used sticks to trace a few simple images in the sand. ....But the stick is no longer made of wood; over the ages the place of wood has been transformed into a massive radio telescope." (Lago, 1981, p. 16)

"The view that life is widespread in the universe is theoretical and highly speculative, though it is based on the best theoretical information presently available. ....If we really want to know the truth about extraterrestrial life, we must eventually seek it in some of the places where it may be found. .... The question is, how can we best do it? ....It is clear that the search for life within the solar system will require generations, if not centuries to carry out even in a limited way. ....Since the discovery of extraterrestrial life forms would be of great scientific and cultural importance, it is time we return to the quest.

"Just as people gradually extend their vision from self-preoccupation as children to identification with a wide community as adults, so in the coming centuries the human species may prefer to be a local representative of Universe-life rather than exist alone in a vast and sterile void. If so, this shift in attitude may prove to be the most important outcome of a successful search for extraterrestrial life." (Feinberg & Shapiro, 1980, p. 16)

INTERSTELLAR TRAVEL

"There is a formidable problem to be resolved before interstellar travel can become a reality. The vast distances that exist between stars are difficult to comprehend. For example, if we drastically shrink distances, visualizing our sum to be a sphere the size of a basketball - about 30 yards away we would see a planet - Earth. This body would be about the size of a popcorn kernel. Next, we begin to walk and start passing other small spheres. These are the other planets in our solar system. After walking one mile we will have passed the farthest in our solar system - Pluto.

If we were to continue moving along this compressed scale, the nearest star would be another basketball-sized body some 5,000 miles distance! Translating this to earth-distances, were we to begin our journey walking ..."in San Francisco, we would be out of our own solar system before we reached the city limits, but we would not reach even the nearest star until we had traveled to London!" (Rood & Trefil, 1981, p. 208.

Such immense distances which are involved in interstellar travel have made many eminent scientists conclude that our human race, (as well as any extra-terrestrial civilizations) will not ever reach the stars. Their reasoning is predicated .... "on two assumptions:

1- It is physically impossible to accelerate any object to speeds greater than the speed of light.

2- The round-trip time required for an interstellar voyage must be such that it could not be accomplished in a human lifetime."

(Rood & Trefil, 1981, p. 208)

The theory of relativity sets the first of these two limitations. One might speculate, as in science fiction, that there could be ways of getting around this limitation, yet there is presently ...."absolutely no firm reason to suppose that this limitation will ever be relaxed. ....

"For all but the nearest stars, the theory of relativity guarantees that requirement 2 will not be met. Even if we neglected the time it takes to accelerate and deceelerate a spaceship, a speed-of-light round-trip to Tau Ceti, the nearest sol-type star, would take about forty years. In fact, ... most starships that people have thought about up to now are more likely to have topspeeds nearer 1/10 the speed of light than the speed of light itself. Such ships would accelerate and decelerate slowly, so that even a one-way trip to Alpha Centauri, the nearest star, could take well over a century." (Rood & Trefil, 1981, p. 209)

It is, however, significant to note that the above-cited facts need not preclude interstellar travel in the future. By the time stellar travel may become a reality, there will probably have been many generations of human beings who literally will never have set foot on the surface of Earth! For these space colonists, whatever they do when they arrive at another star, ... "it is clear that once we admit the possibility of one-way multi-generational travel, the stars become accessible to the human race and any other race that wants to colonize them." (Rood & Trefil, 1981, p. 209)

The Starships

It may be strange, but it is nonetheless true - .... "people have been thinking about the design of interstellar ships for longer than they have been thinking about space colonies. Many ingenious designs have been developed, most utilizing existing technology or anticipated in the foreseeable future. These would not necessitate scientific or technical breakthroughs, ..."although it is usually assumed that a fairly high level of space-manufacturing skill will have been achieved by the time construction of the ship is started." (Rood & Trefil, 1981, p. 210)

Such space ships are visualized to be ... "huge structures assembled completely in zero-gravity conditions of deep space. The material for them would probably come from the asteroids and their crews would come from O'Neil colonies. In every sense, the starships would be creatures of space. They would be born in space and would never enter a planetary atmosphere, much less land on solid ground. This means that the strength of the construction can be a good deal less than it would have to be for a vehicle of the type encountered in science fiction novels, where ships flit between stars and land on planetary surfaces." (Rood & Trefil, 1981, p. 210)

Within the principles which are presently known to work, even if all of them do not hold up after extensive engineering studies, it appears reasonable to assume that at least one of them will come through with flying colors. Further - "assuming that no major new technologies are developed because of the move into space, and even assuming that that the next three hundred years will produce no new technological innovations, when the time comes to start moving away from the solar system, the means to do so will be at hand. ....

"Since the principles involved in all of the starship designs are available to anyone who studies physics, the conclusion that other technological civilizations will also develop the capability of spreading among the stars is

inescapable. The question we must ask then is how long it would take us, (or any other starfaring race), to spread out and occupy the entire galaxy." (Rood and Trefil, 1981, pp. 215, 216)

Where is Everybody?

"Our conclusions on space colonies and interstellar travel are so important and far-reaching that we will summarize them:

1- Within a century, a contingent of human beings can be living in O'Neil colonies away from the earth.

2- Within a few centuries, the entire solar system can be colonized.

3- Using design concepts already in existence, multi-generational ships can be built that will be capable of reaching the stars. Furthermore, people used to living in O'Neil colonies will not find life aboard such ships particularly difficult.

4- With quite conservative assumptions, the time for the human race to colonize the entire galaxy is about 30 million years: (if we can manage not to annihilate the human race before then).

5- Any technological civilization should be able to go through the same process of expansion as we have outlined for humanity."

(Rood & Trefil, 1981, p. 217)

It is a well-established fact - the sun is a relatively young star. Before the birth of the solar system, stars like our sun existed for several billion years. Therefore, if the original Green Bank equation is believed to be a reasonable approximation of reality, ... "there should have been millions of civilizations in the galaxy that reached our own present level of sophistication at least 30 million years ago. And now the connection between space colonies, interstellar travel, and extra terrestrial intelligence becomes evident:

> If there are a significant number of advanced civilizations in the galaxy, at least one colonization front should have reached us by now."
>
> (Rood & Trefil, 1981, p. 217)

And so - the question is again posed: 'Where is everybody'? If one civilization could colonize the galaxy in some 30 million years, and if it is accepted that billions of years have transpired ... "since the first such civilization was supposed to arise, how can we explain the total lack of evidence for an extraterrestrial presence on earth?" (Rood & Trefil, 1981, p. 217)

Professors Rood and Trefil reason that either:

"1- we are the first civilization in the galaxy to reach the technological state, or

2- some other race is now expanding into the galaxy, but just hasn't reached us yet." (Rood & Trefil, 1981, p. 218)

They go on to note that if we are, in fact, alone in our ability to move into space, then it would be pointless to search for an advanced civilization since no such civilization exists to answer our communication efforts.

They conclude that although it is not impossible for such a coincidence to occur, ... "it is extremely unlikely that it could happen more than once - that is, that there should be more than one other expanding civilization. The absence of an extraterrestrial presence therefore leads immediately to the conclusion that there are only a few technological civilizations in our galaxy." (Rood & Trefil, 1981, p. 218)

In answer to the question - where are they - professor Rood offers the following: "At the outset I'll say that I don't know. But I am not at all convinced that they aren't there, so long as we don't question their motives for leaving us alone. ... they're there, maybe at Tau Ceti. They don't communicate with us because, frankly, they don't give a damn. They received our first 'I love Lucy' (carrier) about 1970. Their first ships are on the way and will be here in 200 years. (Rood & Trefil, 1981, p. 219)

> "Today the state of the planet is a major source of concern. We are entering a gigantic 'count-down' with no easy way to measure the time. Monumental changes in Earth's tropic zones, and subtle changes in its marine environments, are occurring. They may produce irreversible effects on the ability of the planet to support what we consider to be a normal pattern of sustainable human life." (Ripley, 1981, p.12)

"We are fools if we don't try. The costs are small compared with other items, such as the defense budget. Still, the (short-term) cost-effective and back-to-earth types may succeed. If the United States as a country turns its back on the possibility, it is destined to be a second-rate power. If the world as a whole rejects the idea, we shall become part of the estimated 15 percent of societies which degenerate.

"The only way to go is up." (Rood & Trefil, 1981, pp. 243, 244)

Professor Trefil offers the following in answer to the question - "what if we are alone"?

"If I were a religious man, I would say that everything we have learned about life in the past twenty years shows that we are unique, and therefore special in God's sight. Instead I shall say that what we have learned shows that it matters a great deal what happens to us. We are not the snaildarters of the galaxy - one more life form whose ultimate fate is of little moment in the grand scheme of things. If we succeed in destroying ourselves, it will be a tragedy not only for the human race but for the entire galaxy, which will have lost the fruit of a 15-billion year experiment in the formation of sentient life. ....

"Perhaps the most important conclusion about immediate action that we can reach....is to realize the tremendous importance of a vigorous program to exploit the near-star space. The ultimate goal of such an endeavor is nothing less than the continued existence and expansion of the human race beyond the next

century. The cost is low if the benefits of spinoff technologies are taken into account. ....

"If we do indeed follow the path of expansion into space, then the first extraterrestrials we will meet will be our own grandchildren." (Rood & Trefil, 1981, pp. 252, 253)

And finally, the major points on which professors Rood and Trefil agree are:

1- The number of advanced civilizations in the galaxy is small.

2- It is entirely possible, perhaps even likely, that we are the only advanced race in the galaxy.

3- We cannot rule out the possibility that there are a few others, although there is no evidence to support this view. (underlining added)

4- Nevertheless, it is definitely worth looking for evidence of ETI because the payoff of a positive search result would be very high.

5- The future of the human race is intimately tied to our ability to exploit the resources of space, a process that will ultimately lead to the existence of space colonies." (Rood & Trefil, 1981, pp.254-255)

THE UNITED STATES AND SOVIET SPACE PROGRAMS

"The U. S. and Soviet space programs are both large and comprehensive, competing across a broad spectrum of military applications, civil applications, orbital science, and deep space exploration. In recent years, the Soviet program has been the larger of the two, but answering who is ahead involves complex qualitative judgements." (Sheldon, 1980, p. (IX))

"The space program is no subject or minor concern. By September 30, 1979, the United States had spent about $108 billion on its combined civilian and military space program, and over half a million people have been employed directly in our space endeavors. No corresponding data are available from the

Soviet Union because of their policy of secrecy in this regard, but considering the physical evidence of space activity, the likelihood is that in real terms, they have committed a similar amount of resources." (Sheldon, 1980, p. 1)

"As a contribution towards detente, and as a spur to the development of universal, androgynous docking system, the United States and the Soviet Union agreed to work cooperatively to develop and conduct a joint flight in which an Apollo carrying a special docking module would rendevous and dock with a modified Soyuz. The flights began on July 15, 1975. The Soyuz 19 was sent up from Tyuratam with Lenov and Kubasov, and the Apollo from the Kennedy Space Center with Stafford, Stayton, and Brand. The two crews paid exchange visits after docking and did joint experiments with the Soyuz returning to Earth after 6 days and the Apollo after 10 days." (Sheldon, 1980, p. CRS10)

"How much manpower is engaged in space work? In the United States, the National Aeronautic and Space Administration (NASA) programs alone at its peak employed about 400,000 people (with 7 percent of them on the NASA payroll), but now has dropped to about 150,000. There were probably about 600,000 people at the peak employed in total U. S. space work. .... The Soviet workforce may be close to 600,000 people because their effort today seems to be at least equal to our 1966 peak." (Sheldon, 1980, pp. CRS - 19, 20)

"Future Direction for the Space Program

Attempting to predict the future of the space program is a difficult assignment as it depends upon political decisions as much as on technical capabilities. At least, there are more engineering possibilities than there are financial resources likely to be made available to pursue them. The issue of future goals has been with the United States for several years, particularly after the accomplishments of the dominating Apollo mission.

"Estimating what the Soviets will elect to do in space may be even harder for a Western observer because of Soviet restrictions on freedom of information.

The United States abounds in paper plans, but until the President and the Congress agree on funding, U. S. plans stay on paper, and there is no formal commitment to go ahead. In the Soviet case, they have stated at several levels of authority, including the highest, more positively their long-range goals, although without a real, public timetable. They, too, undoubtedly have to face hard budget choices before actual hardware work can begin.

"The announced Soviet goal is a comprehensive exploitation of space technology including the exploration and settlement (where practicable) of the planets, along the way exploring the Moon in greater detail, and using Earth orbital stations for a host of practical purposes." (Sheldon, 1980, p. CRS-75)

"The Space Shuttle: What are the Implications for each Country?

....NASA is not only staking on the shuttle its only chance to continue a manned program, but is predicating its unmanned flights on use of this system as the most economical way of making future progress. (Sheldon, 1980, p. CRS-75)

"Not often do machines, in themselves, capture the imagination of mankind. But shortly after dawn on Sunday, April 12, (1981), Americans shared a moment of pride and wonder as a spaceship unlike any other ever built, rose from its Florida launch pad with a dramatic roar, its twin, solid-fuel rockets belching pillars of fire. Snub-nosed and stubby-winged, the strange, 122-ft--long craft was Columbia, the world's first space shuttle. ....

"Nothing quite like 'the marvel', as U. S. astronauts nicknamed the shuttle, had ever flown before. Not the Apollo moon ships, not the cavernous scientific outpost called Skylab, not the increasingly sophisticated space stations lofted by the Soviets. The shuttle is a hybrid, a cross between a rocket ship and a winged aircraft. After looping the earth 36 times, it did not splash into the sea, never to be used again. Under the control of its computers and the skilled hands of its bespectacled commander, John Young, then 50, a veteran Navy test pilot, it glided to a breathtakingly smooth landing on the Mojave Desert at

Edwards Air Force Base, Calif. Seven months later, the good ship Columbia climbed into orbit again, becoming the first spacecraft to fly more than once. ....

"What made the shuttle so significant is that it is the world's first space cargo ship, capable of lofting into low-earth orbit up to 65,000 lbs. of satellites, scientific and military hardward and, perhaps most important of all, components for permanent bases in space. The shuttle makes it possible to move beyond the exploration of space to its exploitation for the world's benefit. Columbia's distant successors, for example, might help set up gravity-free factories or large solar arrays that convert sunlight into electricity for earth. Said NASA's new boss, James Beggs: 'With the shuttle and the other extensions of our intelligence that we have sent into space, we have begun a voyage of discovery that may never end.' ....

"In the end, Columbia had flown. And Americans, witnesses to another landmark event in the 20-year history of man in space, could share the enthusiasm of Astronaut Bob Crippen, as he watched the earth recede: 'What a feeling! What a view!" (TIME, December 1981, p. 37)

"The Soviet Union has shown an equal awareness of the potential of re-useable vehicles, and various Russian space officials have stated their own convictions that such development is essential. But in keeping with Soviet practice, internal debates, or even discussions without debate, about new technology are not exposed in any public forum, so the current status of Soviet effort, if any, in this regard is not known. Considering the Soviet effort to maintain a position of leadership in space, and the continued high level of Soviet activity, (triple that of the United States), they have even more compelling reasons to develop a reusuable shuttle as a cost saving device. It is hard to imagine their attainment of announced goals.... without use of a shuttle. Yet the Soviets have not announced or claimed that they have sucessfully developed such a space shuttle.

(Of interest, however) ... "The U. S. trade press in 1978 claimed a Soviet reusable orbiter had undergone drop tests from a Tu-95 bomber. Unexplained reentry tests in 1977, 1978, and 1979 could conceivably relate to a Soviet Shuttle." (Sheldon, 1980, pp. CRS-75, 77 & 78)

"Manned Space Station in Earth Orbit: What are the plans of each country?

The United States cancelled Apollo lunar landing missions after Apollo 17 and made available for space station work a Saturn V launch vehicle from the remaining small stockpile, now that production of these launch vehicles has ceased. Its experimental space station was called Skylab, and was launched on a Saturn V in 1973. ....It fell from orbit in 1979 with some debris recovered in Australia. ....

"In September 1969, a special task group reporting to the President recommended a four-element program for the 1970's which included the already mentioned space shuttle, a versatile space tug for extensive maneuvering in orbit or landing on the Moon, a nuclear-powered ferry for transfer between Earth orbited lunar or planetary orbits, and a building block system of modules to construct permanent space stations in Earth orbit, and elsewhere. The program was carefully considered technologically, but it involved fiscal peaking problems which were given small chance of winning general national support. Hence, the present effort to build the shuttle is the only one of the four elements recommended by the Administration for active development, (aside from solid-fuel upper stages).

"Part of the gap in the U.S. program will be filled by the Europeans, who are building a manned sortie module (Spacelab) to be carried in the shuttle. But because it is not detached from its shuttle ferry, it is not a real substitute for any proposed station modules.

"Only the low level study and component development is underway for a U. S. space station module, as a potential follow-up to the interim Skylab. The paper concept calls for 12-man modules to be carried to orbit by the shuttle, and then could be linked to make versatile stations housing up to 100 scientists and

engineers with stay time ranging up to one year. Modules would be built for various functions and then joined to meet needs. While the main shuttle would be in a fairly low Earth orbit, later modules might be used for other purposes such as 24-hour synchronous high orbit, lunar orbit, and deep space flight. (underlining supplied)

"The Soviet Union claims that its docked combination of Soyuz 4 and 5 in January 1969 represented a rudimentary space station, inasmuch as there were four rooms assembled with four men present. ....

"The Salyut space stations from 1971 on can make a real claim to their title, even though the overall 25,000 kilogram-combined weight (with Soyuz), and 200 cubic meters of interior space fall well short of the 82,235 kilogram and 357 cubic meters of Skylab. The advantage of Salyut is that it is an on-going and evolving program. The sixteen flights to Salyut 6 have borne this out.

"For the future, the Russians speak confidently of building a large and permanent orbital station for many men, for the purpose both of conducting Earth application work and scientific observation of the stars, and additionally serving as an orbital assembly checkout, and launch facility to send manned expeditions to the Moon and planets. Keldysh, the President of the Soviet Academy of Science, predicted in October 1969 that such a large station might be ten years away but would more likely be available in five years. (Note: it is not yet here!) .... It may be that the long-awaited large (G) launch vehicle will find use in lifting major components for such a station. Using their vehicle, the U.S.S.R. could put up its equivalent of the U. S. Skylab anytime from 1980 on. At the moment, orbital assembly of small components seems a more likely path. There is more press and professional discussion world-wide than firm planning for space colonies. A favorite scheme is the L-5 proposal to be positioned in Earth orbit as far away as the Moon at a Lagranian point." (Sheldon, 1980, pp. CRS-78, 79 & 80)

What are the prospects for manned flights to the planets?

"For a number of years, NASA has studied various kinds of manned planetary expeditions, principally to Mars. ....When the President's Space Task Group in the summer of 1969 submitted its long-range U. S. space plan, it opened the possibility of a Mars landing by men in the 1980's.

"The general reaction in the Congress with few exceptions was either indifference or active hostility, and NASA has not pressed this possibility in its official plans.

"An mentioned earlier in this paper, a national capability to use space in the late 1970's and thereafter was built around use of four types of largely reusable and multipurpose vehicles. The shuttle, already discussed, was not intended to be an end in itself, but represents a design approach to cutting costs and adding capacity for all kinds of missions, whether unmanned or manned, and whether in Earth orbit or beyond. The second element, already discussed, was the manned station modules. This was expected to justify its costs of development and use in practical applications in Earth orbit once such a reliable unit was available, and the shuttle permitted non-astronomers and less expensive payloads to fly to and from orbit safely at moderate cost. Purely as a dividend, such a unit could also have used at nominal additional cost in orbit around the Moon, on the surface of the Moon, and for flights to planets.

"A third element was a spacetug, to have been used in assembling components in the vicinity of the future permanent space station shifting payloads to synchronous orbit, or landing major components on the moon as successor to transport capabilities of the Apollo lunar module.

"Only the fourth element of the proposed national program was aimed primarily at deep space work: the nuclear-powered orbital transfer shuttle, also reusable, both for major movements to and from the Moon or in planetary flight. (Now of course, all nuclear propulsion development has been halted).

"When members of Congress reacted so negatively to the report of the Space Task Group, the very existence of the shuttle, which was intended to be so important to cutting costs near Earth, was threatened by the charge that it represented a back-door attempt to gain a manned planetary program without explicit approval. Consequently, little about planetary flight has been said since then by NASA in connection with the shuttle or other program elements. ...

"As already indicated, the Soviet Union has talked more positively about manned flight to the planets (even as recently as 1978 and 1979), and it is hard to doubt their ultimate intentions in this regard as one studies their total program effort. But to carry out such flights will face them with the same technical and financial problems which the United States will have.

"This brief review does not assess the ultimate consequences of pursuit of such goals or failure to undertake them. ....It is hard to accept philosophically that mankind would forever exclude the possibility of visiting most parts of the solar system. The late President Eisenhower saw practical reasons for limiting space expeditions, but even his first public report on space goals accepted in principle flights by men to Mars, as have most other U. S. Presidents since that time." (Sheldon, 1980, pp. 84, 85, & 87)

CONCLUSIONS

The facts and probabilities discussed in this document suggest that life is more surprising than fiction. In reality, fictions are but reflections of life, and each moment of life can bring a totally unexpected surprise. Only when one is shocked into wakefulness is one also shocked into an awareness that life is viable; i. e., ever-changing; never static! One should alert one's senses to the mystery of life as we sense it and to the likelihood that extra-terrestrial life does exist.

"Can we reach the stars?

Some scientists think that we will never reach the stars, that time will forever keep us prisoners of our Solar System home. However, people once scoffed at the idea of huge machines carrying passengers through the air over the oceans, and of rockets sending people to the Moon. Yesterday's science fiction often becomes today's science fact.

It is hard to single out any one reason for venturing into space as the most important, for there are many important reasons. One is to give Earth a way of harnessing energy more efficiently. Another is to find out about other planetary systems and other stars in order to better understand our own Solar System home. And finally there is the driving curiosity to know whether we are alone in the Universe or whether intelligent beings and advanced civilizations abound out there." (Gallant, "Our Universe" 1980, p. 262)

In our awareness of the cosmos, there is a vast difference between knowing and knowledge. On the one hand - knowing is experience; on the other hand- knowledge is but borrowed information. At the present moment we do not know, (i.e. experience) that extraterrestrial life exists. However, our knowledge, (i.e. borrowed information) about such a possibility continues to grow. Therefore, it is entirely reasonable to suggest that we may yet come to know, (i.e. experience) contact with extraterrestrial life-forms. What an exciting prospect for the inhabitants of the spaceship Earth!

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References

Asimov, Isaac — "Extraterrestrial Civilizations." New York, Crown Publisher, Inc. March, 1979.

Berendzen, Richard — "Life Beyond Earth & Mind of Man." Washington, D. C. NASA, Scientific & Technical Information. U. S. Gov't Printing Office, 1973.

Bracewell, Richard — "The Galactic Club." California, Stanford University Alumni Association. 1974.

Bylinsky, Gene — "Our Cosmic Cousins." Science Digest: September 1978.

Calder, Nigel — "Spaceships of the Mind." New York, The Viking Press. 1978.

Clark, Arthur & editors of LIFE — "Man and Space." New York. TIME, Inc. 1964

"The Exploration of Space." New York, Harper & Row, Publishers, Inc. 1968.

"The Coming of the Space Age." New York, Meredith Press. 1967.

"The Promise of Space." New York, Harper & Bros. 1959.

Cooper, Henry, S.F. — "The Search for Life on Mars." New York, Norton, 1980.

Dwiggins, Don — "Into the Unknown"(The Story of Space Shuttles and Space Stations): San Carlos, Calif. Ryan Publishers. 1971.

Feinberg, Gerald & Shapiro, Robert — "Life Beyond Earth: The Intelligent Earthlings Guide to Life in the Universe." New York, William Morrow & Co. Inc. 1980.

Foster, G. V. — "Non-Human Artifacts in the Solar System." Spaceflight, V. 14: December 1972.

Gallant, Roy A. — "Man's Reach for the Stars." Garden City, N. Y. Doubleday & Co., Inc. 1971.

"Our Universe: National Geographic Picture Atlas of." Washington D. C., National Geographic Society, 1980

Gliedman, John — "Worlds in Slow Motion." Science Digest. August 1981.

Golden, Frederic — "Colonies in Space." (The Next Great Step). New York. Harcourt, Brace, Jovanovich. 1977.

Goldsmith, D. & Owen T. — "The Search for Life in the Universe." Menlow Park, Calif. Benjamin Cummings, 1980.

Heppinheimer, T.A. — "Toward Distant Suns." Harrisburg, PA Stackpole Books, 1978.

Lago, Don — "Symbols of Mankind." Science Digest. March 1981.

Macgowen R. & Ordway, III Frederick — "Intelligence in the Universe." New Jersey Prentice Hall. 1966.

Macvey, John — "Journey to Alpha Centauri." New York. The Macmillan Co., 1965.

Morrison, Philip & Billingham, John — "Search for Extraterrestrial Intelligence: SETI." Washington, D. C., Gov't Printing Office, 1977.

Michaud, Michael — "Interstellar Negotiations." Foreign Service Journal. V. 49. December 1972.

"Negotiating with other Worlds." The Futurist, V. 7, April, 1973.

Ripley, S. Dillon — "The View from the Castle." Smithsonian, Dec. 1981.

Rood, Robert & Trefil, James S. — "Are We Alone? The Possibility of Extraterrestrial Civilizations." New York, Charles Schribner & Sons, 1981.

Sagan, Carl — "Communication with Extraterrestrial Intelligence (CETI)." Cambridge, MIT Press. 1973.

"The Cosmic Connection." New York, Doubleday, 1973.

"Brocca's Brain." New York Random House, 1979.

Sagan, Carl & Drake, Frank — "The Search for Extraterrestrial Intelligence." Scientific American. V 232. May 1975.

Sheldon, William — "American Space Exploration: The First Decade." New York, Little, Brown & Co., 1967.

"Man's Conquest of Space." Washington, D.C. The National Geographic Society, 1968.

"Soviet Space Exploration: The First Decade." New York, Washington Square Press. 1968.

Sheldon, II, Charles — "The United States and Soviet Programs in Space: Summary Data Through 1969 & a Forward Look" Washington, D. C. Report - Library of Congress: Gov't Printing Office. 1980.

Shklovski, I. S. & Sagan, Carl — "Intelligent Life in the Universe." New York. Norton, 1967.

"Possible Uniqueness of Rational Life in the Universe." Washington, D. C. NASA Technical Translation TTF-17. Gov't Pringint Office, 1977.

"Stars: Their Birth, Life & Death." San Francisco. W.H. Freeman, 1978.

Smith, Marcia S. "Possibility of Intelligent Life Elsewhere in the Universe." Washington, D. C. Congressional Research Service; Library of Congress: 95th Congress, 1st session: 1977.

Sullivan, Walter "We Are Not Alone." New York. Holt, Rinehart & Winston, 1972.

TIME "Blazing the Way to the high Frontier." January 1982: p. 83.

Vershuur, Gerrit "Is the Cosmos Alive?" Science Digest. July, 1981.

von Braun, Wernher "Space Frontiers." New York. Holt, Rinehart & Winston. 1967.

von Braun, Wernher & Ordway,III, Frederick "History of Rocketry & Space Travel." New York Thomas V. Crowell Co., 1975.